The Earth is Alive
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François Derrey

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Is the Earth Alive?

Aspects of the Earth

There are as many ways of speaking of things as there are of seeing, feeling, or understanding them. The earth is no exception. Is there a way of speaking of things that is truer than another? The nineteenth-century scholar saw fit to answer in the affirmative. We in the second half of the twentieth choose to say that there is not. The reality of a thing is the sum of the aspects which it assumes, and each of these aspects has a measure of reality and truth for at least one observer.

What of science? And, in particular, what of geology? The answer to the latter question is implicit in this book. A book of this kind had to be written by someone who was not a geologist, and who because of this was not inclined to make a choice and still less tempted to impose it on the reader. The reader will approach the earth as it should be approached: through science and through poetry, through the perception of twentieth-century men of science and through the myths expressed in the past by the collective unconscious of mankind; through contradictory theories: in a word, through the history of various aspects of the earth.

As he proceeds, the reader should refrain from trying to form an opinion unless he is forced to—as is the professional geologist—by some external necessity or by some profound impulse of his temperament. The cultivated man does not need to have an opinion on everything; with every opinion there is undoubtedly a corresponding curtailment of reality—sometimes a necessary curtailment.

Scientists have always been researchers, and the progress they made was often the result of their faith in the absolute value of one of the aspects of external reality. If nineteenth-century scientists
had not resolutely believed in the ultimate reality of matter, we
would not be enjoying today the vision of a vigorous universe or
our partial mastery of it.

If I have chosen this example, it is because it is of very special
relevance to our vision of the earth.

The word "earth" means two things:
—on the one hand, a body to which we assign a shape, and
whose insertion into the cosmos we find convenient to explain by
considering that it is animated by certain movements; this satisfies
the needs at least of some inquirers, notably astronomers, in the
present state of their science;
—on the other hand, a substance of which any of us may pick
up a handful or break a piece, according to whether we are walking
on it in a crumbling or a rocky state.

I shall consider here only the matter earth, which I have studied
for many years. I was taught that it has a heavy core consisting of a
fusion of nickel and iron, surrounded by a layer of silicon—
magnesium, which in turn is surrounded by a crust of silicon—
aluminium—each layer having a lesser density. But I was told
later that the supposed nickel–iron core could be highly com-
pressed helium.

It was explained to me how matter in fusion could erupt
through the solid crust in volcanoes and also penetrate this crust
without cracking it and, by cooling, form "intrusive" crystalline
masses in the superficial sedimentary rocks. But others said that the
sedimentary rocks crystallize themselves deep in the interior. Now,
how do we determine the origin of such crystalline rock?

And how can we know what part each of the diverse categories
of forces—internal, surface, vertical, tangential—plays in the
formation of a chain of mountains—forces to which a portion of
the earth's crust can be subject at a given moment?

These examples show the uncertainty which characterizes the
examination of the earth: the essential point escapes our observa-
tion. A fortiori, the history of the earth can be reconstructed only
with great caution, for who can know what was happening three
billion years ago?

Among sciences, geology allows of an exceptionally high
proportion of hypotheses, and these concern the very constitution and structure of its object. It is not surprising that numerous contradictory theories confront one another.

Underlying all the hypotheses about the formation of rocks and mountains is one which has assumed the form of a postulate in the minds of men: the inertia of mineral matter. The cleavage between so-called “living” matter and “inert” matter is a deeply rooted notion, as deeply rooted as the supposed unchangeability of matter.

But the instability of radio-active elements has now been shown; and Louis Kervran has for some years been publishing observations and the results of experiments which extend the property of transmutability to many other elements. The first of these experiments concerned the biological metabolisms, the most recent bringing out the change in metals by the action of living organisms. Whatever resistance may still be offered in regard to the new discoveries, we must accept the inevitable and admit that, in Nature, sodium can become potassium, iron can become manganese, etc. And we do not have the right to fix a priori limits to this, any more than we have the right, since Piccardi’s experiments, to put limits on the cosmic radiations which can influence the unfolding of the physico-chemical processes that transform our matter.

If we remain compelled by the present state of our senses to see only “matter”, we should begin seriously to think “energy”. In particular, we should try to consider matter-earth in a universe of energy.

In such a universe our partitions are disappearing. This is undoubtedly what Melvin Calvin, 1961 Nobel prize winner in chemistry, was thinking of when he wrote: “Our greatest advance [in science] is perhaps in the hands of men who are inclined and fitted to ignore the artificial classifications which we have built up, men who will instinctively weave these classifications into the pursuit of an idea.”

It seems, indeed, that inert matter and living matter are two elements of one of these artificial classifications. For some time now “forms of passage”—the crystallizable viruses—between the two domains have been pointed out. The problem is not there, except in so far as a relationship can be established between the
living cell and the crystal. The question is one of energy structures.

We owe to the new structural approach, cybernetics, a curious proposition made in 1938 by J. Polonsky. This physicist, assigning a specific function to each of the constituents of the living cell (nucleic acids, proteins, enzymes, etc.), shows that the cell as a whole may be considered as an electromagnetic microcybernetic system; thus he succeeds in suggesting satisfactory explanations for phenomena like the biosynthesis, photosynthesis, conservation, reproduction, and mutations of cells.

The extension of such ideas to the crystal could have appeared absurd as long as some remarkable structural analogies between metals and enzymes had not been underlined. Today, not only are these analogies known, but they explain the functional role played in the biological processes by certain metals in the state of traces or in a finely divided state ("oligo-elements"). Yet it remains evident that the homologous minerals of many transformations of living matter are still to be discovered. It is doubtless a question of optics.

In effect, the argument which could appear decisive in the separation of the two worlds, mineral and living, might be found in the fact that life produces negative entropy (see especially Schrödinger). This means that life is capable of draining part of the available energy to create order, countercurrent to the so-called universal tendency (another "law" to be modified) toward the augmentation of entropy, that is, toward debasement, toward disorder. I shall try later to show that the phenomenon of crystallization of the sedimentary rocks into granitoid rocks may be considered as a process contrary to the entropic tendency in the evolution of the earth.

The least one can say is that the border lines between the two worlds are rapidly becoming blurred and that by superimposing the classifications one discovers homologies or analogies which singularly limit the scope of validity of these classifications.

A WORLD WITH NO FRONTIERS

The observable interaction between the mineral world and the living world accentuates the elementary similarities which I have just underlined. Without mentioning the increasing realization of
the extensive role of living beings in the transformation in rocks, a subject to which a chapter is devoted in every textbook, I shall draw attention to the following facts:

On the one hand, bacteria are now used to separate metals in certain treatments of minerals, it having been discovered that they have a part in the formation itself of certain metalliferous concentrations—that, by reason of the aptitude of bacteria for modifying the potential physico-chemical conditions of certain environments.

On the other hand, we now know and use the ability of some metals to modify the physico-chemical potentials of biological environments, as I have already mentioned.

In both cases, it is a question of presence which we connect, rightly or wrongly, to the phenomena of catalysis (the name matters little), but which is shown to be of a fundamentally energetic nature.

Thus we see elements as characteristic of "inert" matter as metals are (according to classic views) fulfilling a function in the biological processes. Why, then, should they not perform functions in their own world seen not from the angle of inertia but from the angle of a harmony of energy in perpetual development?

If biology studies parts and wholes, from the elements of the living cell to the organic unity of living beings (tissues, organisms, organs, associations), the science of the earth applies to parts and wholes from the elements of the atom to the total system of the planet (crystals, minerals, rocks, families of rocks). Such a structural similarity between the living world and the mineral world should be taken into consideration by investigators. After the differences have been observed with the eye, the homologies should be carefully sought out by the mind. I do not believe that the geological method can bring anything to biologists; but I am convinced that, inversely, more biological optics, freed from the advocates of a priori immutability, would be extremely fruitful for geologists.

In this optics a differential factor is imposed: the time factor. We know that some biological phenomena operate by small stages, at a rate of one to a hundred per second, and become perceptible after a very short lapse of time. Geologists must count in thousands of years the time necessary for the slightest change in their material
to become perceptible. This time scale helps to give the substance of the earth its appearance of fixity. We should stop being deceived and consider that if it were possible to record on film what happens in a granite rock during a million years and then run the film in an hour, although it might show us nothing, we might also have the shock of seeing changes unfolding which were very lifelike.

The special temporal aspect of geological phenomena has induced geologists to pay too little heed to the time factor. They undoubtedly ought to add time to the two factors of temperature and pressure which they tend to consider alone in the transformation of terrestrial substance. That would limit the extrapolation of their laboratory experiments into the natural environment, which would considerably purify the atmosphere of “earth research”.

“Duration,” said Herodotus, “makes everything possible.” Is not time the fourth dimension of all reality, that which imposes evolution on it? Thus we led to envisage the mineral world, like the living world, as a structural jointing which evolves in time; as a harmony where each component is characterized on the elementary scale by its structure, but is defined on the scale of the whole by its functional role. That is the earth we still have to find.

In such a perspective, a piece of earth which we pick up or break has no more meaning in itself than the photograph of a man at any moment whatsoever has in regard to his entire life—still less by comparison with the life of the earth. Appearances give precedence to evolution, structures to processes. Life takes on its full meaning; and we wonder how and why the earth could elude us.

The Allegorical Earth

The first verse of Genesis states quite precisely: the heavens and the earth. But it has been shown that this demotic translation from the Hebrew text masks “Involution and evolution, being and becoming, extent and movement, or, more simply, the archetype of all duality and all polarity” (Abellio, 1950).

The earth and the heavens may therefore be considered as forming a pair, according to the fundamental law of the universe that nothing happens in an environment in equilibrium; for some-
thing to happen, a polarity must be established. This first truth has been expressed in innumerable more or less symbolic forms, from the Chinese Yin-Yang up to Bergsonian current of matter and current of life, passing through all the aspects of sexual coupling—all this only serving to illustrate the Vedantic principle of the duality inherent in every manifestation, in all creation.

Does this have anything to do with our matter earth? Before replying, let me call up another ancient symbol.

It was said by the Greeks that the Demiurge first created four “elements”: fire, earth, air, water. These four words—and the order in which they follow one another—clearly have a symbolic value which serves as a base for what it is convenient to call tradition; but it happens that our matter earth offers a field to which they can be applied exceptionally in their current meaning while still keeping their full symbolic significance.

The most expressive and the most useful diagram which groups the “four elements” is their arrangement in a cross:

```
    AIR
   /    \
WATER  EARTH
   \    /
    FIRE
```

In this diagram we immediately distinguish the difference between the elements on the vertical axis, the immaterial air and fire, and those on the horizontal axis, the two usual forms of matter: water and earth. It is as though there were an energy axis and a material axis. Now, if we try to draw an outline of what essentially characterizes our matter earth, we may put forward the following diagram:

```
    METEORIC ACTION
   /     \
SEDIMENTS    GRANITES
   \     /
MAGMATIC ACTION
```
which takes on its full significance by completing it with an arrow indicating the development of the geological cycle. The analogy between the two diagrams is self-evident, but it requires some complementary developments.

**The Geological Cycle**

The geological cycle includes essentially two opposite phases: the formation of the rocks (lithogenesis) and their destruction (glyptogenesis). Setting aside variables which do not change anything in the fundamental cycle, we may describe the latter by saying that:

—meteoric action (symbolized by air) breaks up the solid rocks which at a given moment constitute the projecting parts of the earth’s crust;

—the products of this breaking-up process are carried (for the most part by water) into deposit areas where sediments accumulate;

—these sediments sink into the crust where they are subjected to high temperatures and pressures even being more or less directly exposed to the action of magma, validly symbolized by fire;

—the magmatic action results typically in a recrystallization along with cohesion of sediments, the final end of which, though rarely attained, is granite, the perfect form of earth.

The four traditional “elements” therefore apply very directly and simply to the phases of the evolution cycle of the terrestrial substance. Let us push the analysis a little further.

Sediments are characterized by the coexistence, among their constituents, of mineral elements capable of combining but indifferent to one another (e.g. calcium and silicon); sedimentary matter is amorphous or colloidal, confused not structured. Sediments represent the entropic pole of the geological cycle.

The elements which take an active part in their composition are metalloids: oxygen, hydrogen, and carbon. With the addition of nitrogen, these are the elements of living matter, with which the mineral world has unusually close contact during the meteoric and sedimentary phases of the cycle.

Unlike sediments, granitic rocks are made up of crystalline structures. The granite world is a closed world which expels all
intruders as it perfects its structure. We find that oxygen has an important role, but in combination with silicon and aluminium, in its fundamental armature. The evolution of this world appears linked to the alkaline metals: potassium and sodium, the first elements which will emerge from the story under meteoric influence; on the other hand, calcium will subsist. Unlike the sedimentary world, the granite world is organized; it is the anentropic pole of the geological cycle.

The change from sediments to crystalline rocks is called metamorphism, expressing the action of the magma. This action is exerted upon the sediments whether by the sinking of the latter into the magma or by intrusion of overflows of magma into the sediments. The magmatic source which releases these overflows is supposedly composed essentially of silicon, iron, and magnesium; but the purely magmatic minerals, iron and magnesium, can enter the granite world only in minute quantities, the granite likewise denying entry to the “heavy” elements of the central core. But what is thus built up by the action of the internal magmatic pole of the earth, will be destroyed by that of the external meteoric pole, which connects the earth to the cosmos. Nothing of what is elaborated in the realm of the “pyrosphere”, the sphere of fire, will resist the mechanical or chemical action of the agents of the atmosphere, the sphere of air, which is etymologically also the sphere of the soul.

Before I explain what the word “soul” is doing here, let us glance over the landscape.

Our horizon is blocked by these arid granite hills encumbered with blocks—like tombstones in a cemetery. These are dying rocks. Far from the heat which gave them birth, they are at the end of their world and their energy, cut off from their alimentary bases, weakened by the very solidity of their structure and organization. The slightest breeze chills them; the least ray of the sun splits them; each rain drop carries away a piece of granite, the symbol of perpetuity!

Meanwhile, at the bottom of the valley the mineral debris accumulates. Water circulates freely among these movable sediments; it decomposes here, dissolves there, removes elsewhere, taking advantage of its chemical and mechanical properties to
discern but also to enrich. Water gives a vital reason to exist to each of the elements freed from the granite prisons. Silicon will nourish the diatoms, calcium and potassium the green plants; sodium will sustain those who are the salt of the earth, aluminium the earth itself.

But in a corner of the landscape there is a cone even more sinister than the granite hills: one of those smoking volcanic silhouettes by which the central fire reminds us of its existence. Tomorrow, perhaps, the ominous cone will spit forth magma which will swallow up the sediments, cut them off from the life of the atmosphere, and return with them to the depths, where, after a long sleep, they will be caught up again in a new cycle of active mineral life. Made fecund once more by the internal fire, they will be able to reconstruct granite, and believe once more in the eternity of their substance.

GRANITIC MAN

Inspired by this landscape, let us resume our meditation. If the four elements have a symbolic value, it is that everywhere there must be found a structure and an evolution analogous, if not actually homologous, to the structure and evolution of the earth. As regards man, in particular, the traditional symbolism may be interpreted by making water correspond to the body, fire to the heart, earth to the intellect, and air to the soul. Note that in this tetrad the intellect has the strict sense of “mental”, leaving the soul its transcendental intuitive function in comparison to dialectical thought.

Since we began the geological cycle with the sedimentary phase, the domain of water, let us begin the human cycle with the birth of the body. The body has a purely existential meaning (and consciousness); it does not in itself prejudge any creative evolution any more than does sedimentary matter; the function of the body and sediment is to prepare a substratum to which the evolutive energy can be applied; the life of the body is itself a sedimentary sleep—that which primitive man experienced.

Then comes adolescence: we are waking up to life, like sediments through magmatic impulse. The heart begins to beat, to
push the individual toward selective affinities to constitute the elementary crystals of mankind. The illusions of the Romantic Age make us regard as ethereal any sediments which are heavy like the heavy elements of the earth’s core, the objects of the first evolutive segregation. We readily look upon our own associations as unusual crystallizations, in the same way in which I imagine the first crystals of aluminium silicate born in the still-amorphous mass of sediments must feel themselves “noble”.

Was it not in this way that group-consciousness began in the bosom of mankind, when each barely formed crystalline network saw around it nothing but barbarity?

But the inner fire demands that “barbarity” be conquered, that the embryonic crystalline network extend in space and proliferate, in the way that metamorphism spreads in the newborn rock. The magma and the human heart both engender a hold on consciousness which is associative and conquering.

The growing complexity of associations still requires that consciousness increase, that it free itself from the weights which hinder it, and that it become refined as it organizes itself. Individuality and its primitive feelings are rejected, just as the newly forming granite frees itself from the heavy elements which hindered the first crystallizations. It took from the magma—and keeps—its alkaline gases. We wonder a little where they come from, like the “sublime” feelings which animate mankind at the dawn of civilization. Human society, like mineral society, is structured at this third phase of development; in both cases organization goes hand in hand with refinement, while the “noble” (alkaline) ideas creep over the mass, modifying the equilibria in a remarkably continuous and inescapable direction. It happens that at one point in the mass the equilibrium is seriously disturbed by a sudden inflow of magma left behind in the unconscious of the earth and of mankind. Revolution... but in the end it only stimulates the drive toward structured equilibrium.

Human nature assumes a granitic consciousness; it ends by believing in the eternity of its institutions, just as granite must believe in the indestructibility of its perfected feldspathic edifices. Organizing, conquering Thought reaches the peak of pride in
stone and in the human spirit. The whole system gives the best possible image of a perfectly homogeneous earth.

Is the geologist the only one to know, in the twentieth century of the highest civilization, that granite keeps intact only as long as it remains in the darkness of the earth? That its coming to the earth’s surface means its end? That the meteoric will laugh at its solidity and reduce it to dust?

The geologist should also understand that the arrogance of human thought is a kind of darkness; that the return of the light, to the cosmic meteoric, to the soul of creation, will demonstrate the vanity of that of which man is now so proud, and will mean the destruction of all the structures of his intellect. Thus a new human cycle will begin, in a reborn humility.

**THE LESSON OF THE GRANITES**

For the geological cycle to be completed, it is necessary that, between lithogenesis and glyptogenesis, the movements of orogenesis take place.

By what is orogenesis expressed? Usually, its chief stages are marked out with the wrinkles which have creased the earth’s crust at various epochs. More modest but no less significant signs are found in the great movements of the sea which make one geological stratum overlap another more ancient stratum irregularly. And each of the great divisions set up by the planet’s sudden jolts is accompanied by a granite peculiar to it. Sometimes granites succeed each other in the same region from which we have discovered that the more recent they are, the more they are “evolved”, alkaline, distinct from their geological context; and the more often they project out of this context the more they are subject to erosion. Each time, erosion can carry away a larger quantity of alkalis—notably sodium—to give them over to marine or organic life.

If Man has not yet succeeded (Scripture says from lack of faith in his own destiny) in making mountain chains rise, he gives us many other orogenic pictures. Above all, he shows us his successive forms of culture transgressing on one another in the manner of
geological strata, with an apparent inconformability which, like the stratigraphical inconformabilities, is founded on the continuity of the evolution of the earth.

And does not logical thought, the psychic homologue of mineral granite, create in each of these cultures a civilization more and more refined with time—more and more "alkaline"? This only proves that in each civilization this thought is more distinct from the mass of humanity and projects farther above its average understanding, like young granite jutting out of its context. Never in the course of history has an "elite" been more out of touch with human (and especially cosmic) reality than that which at present leads the world, in the name of concepts so highly refined that one wonders in relation to what they have meaning.

Yet they do mean one thing: they provide a more and more subtle matter for erosion; matter which, as it breaks up, will be able to deliver a growing mass of alkalis to the suprahuman cycles.

The history of the granites offers men great hope.

Jean Lombard

Vice President of the
International Union
of Geological Sciences
1 | The Magic Globe

Is there anything simpler or more reassuring than our earth? An infinitely large or infinitely small world could make our heads spin and even fill us with terror. But this familiar globe we walk on should arouse in us neither anxiety nor curiosity, for there is nothing really extraordinary to be found here.

We already know so much about its most minute details. This is a planet that is both simple and well-behaved, that revolves upon itself every twenty-four hours, and travels round the sun every three hundred, sixty-five and one-quarter days. It is a world of truths which are commonplace, verifiable, and generally so absolutely reassuring that we may well wonder why our ancestors ignored them with such persistent obstinacy.

But an association to propagate the theory that the earth is flat actually exists today; it is called “The International Flat Earth Research Society”, and has its headquarters at 24 London Road, Dover, England. And although it seems certain that the earth turns, a student at the Polytechnic School (in France) produced a work in 1963 to try to disprove this. And some people see, or have seen, the planet as a live animal, or a hollow globe, a universe that is concave, hemispheric, cylindrical, pulsating, and so on.

Before proceeding, we should accept the initial fact that this earth, which is as familiar to modern man as his daily newspaper, has always been subject to transformation, deformation, and renovation by certain of its inhabitants.

THE EARTH: AN INCREDIBLE STORY

Since a great deal of irrational thinking is involved in this story, our point of view will probably be more valid if we question it in the light of available evidence. Let us try to make sure of our
position by trying a little experiment. Imagine that you have forgotten everything—quite literally everything—that you already know about the earth. Now that you are in a state of amnesia, a scholar comes along to explain to you that the earth is round. You are naturally sceptical, and immediately ask him how people in the antipodes can stand upside down without falling off. His reply will be that this phenomenon is one of the effects of gravity, “a force which seems to pull all bodies toward the centre of the earth”. If you go on to make further inquiries about the precise nature of this force, your companion will become somewhat defensive since he knows hardly any more about it than you do. “Gravity” is a very convenient word used to explain the unknown. It is, indeed, a fact that a man in the antipodes does not fall off. Nevertheless, the word “gravity” does not explain the nature of this phenomenon any more lucidly than the words “soporific quality” account for the effects of opium.

Our scholar goes on to explain to you that the earth turns upon itself and around the sun. A rapid calculation will then show you that, if the scholar is right, the earth is launched on its orbit at a speed of 18.6 miles per second. Our astronomer now proceeds to inform you furthermore that the galactic whirlpool sweeps our planet along at some 170 miles per second and that the galaxy itself shoots through the universe at a dizzy speed. By now you will undoubtedly be casting a pitying glance at this poor madman who actually believes that he lives with his head pointed downward, turning like a chicken on a spit, and being whisked along in a fit of frenzy. His version of the earth seems to be the craziest and most incredible fable ever invented.

It so happens that this insane story is not something we are told in our adult years but is first revealed to us in our classrooms. Our opinions seem to be frozen by the cold, infallible facts found in classroom texts, and we appear to have lost the ability to appreciate the elements of fantasy or of the extraordinary which surround the facts. Copernicus, for example, seems to have been well aware of the fantastic aspects of his own system. We know that the manuscript of his work, *Revolutions of the Heavenly Bodies*, was kept in secrecy by its author for 27 years. In his preface, he excuses himself in a way by presenting this quite extraordinary hypothesis:
“Since astronomers permit themselves to imagine certain circles to explain the motion of the stars, I have come to the belief that I could likewise examine whether the movement of the earth renders more exact and more simple the theory of its movements.”

But for thousands of years, neither schools nor truth existed. Then for a very long time schools were in existence, but the truth was not taught in them. And now that schools are the fountains of truth, it is considered rebellious to refuse to accept what the teacher offers as knowledge and to turn to more exciting or, on the contrary, less disturbing explanations of our universe. This attitude may seem a rather strange one, but is it not equally disconcerting to see how placidly and unquestioningly we accept the most incredible realities? Through nothing less than intellectual sloth, we even go so far as to lower them to the ranks of the obvious.

WE HAVE IMAGINED THE EARTH

But those who are unaware of the truth, and those who reject it, have bequeathed us quite an impressive catalogue of different earths, myths, and legends which spring from the most flamboyant flights of imagination. To start with, the link between earth and man was established on a purely subjective basis or was at least dominated by subjective thinking. According to this angle of vision, the earth is not perceived as a physical phenomenon, objectively observable, but as an assembly of myths and symbols, as a personality such as might be imagined by primitives out of the needs created by their milieu.

However, man soon wanted to know what his country resembled and what was its place in relation to the heavens. There again the human race has hardly been beggarly with its imagination. Practically everything was attempted before we arrived at the Copernican system. Yet the revelation of the truth has only served to stultify the human imagination. In an attempt to counter Copernicus, bewildered souls on our planet have invented earths that do not turn, or which only turn upon themselves, or which are quite satisfied with taking a stroll in the sun. All possibilities
have been taken into consideration on the one condition that they contradict the truth.

What is presented in the following work will most certainly be incomplete. We can only discuss theories that have had a certain claim to fame, selecting the most typical ones without pretending that we are making an exhaustive study, which would only prove to be fastidious without being more significant. We will then be able to approach the history of the earth. Scholars assure us that terrestrial events have evolved in “geological rhythm” which means that they have developed imperceptibly. This is a particularly fruitful approach to such a study. It is precisely from the very acceleration of the phenomena that the spectacular, the marvellous, and the grandiose have been born.

All the traditions and mythologies are packed with planetary catastrophes. We shall focus our attention, however, on two major themes: the Flood and Atlantis. A passion for cataclysms is not confined, however, to ancient civilizations when it comes to trying to explain the earth’s history. Even today, the children of the earth have bestowed upon it an eminently disastrous past, abounding in collisions, explosions, and lacerations.

THE TRUTHS OF MYTHS

“If the earth turned around itself in 24 hours, as certain people have suggested, the points of its equator would move at a fantastic speed, and human beings, houses, stones and water would be hurled into the air; the sun itself would explode in splinters,” wrote the celebrated astronomer Ptolemy.

And as late as 1963, eighteen centuries later, we find that he is being echoed by Maurice Ollivier, an advocate of geocentrism, in his work Modern Physics and Reality: “All these movements which the earth supposedly carries out ought to trouble our atmosphere continually, and we would see their effects everywhere, even if we suppose that gravity sustains this atmosphere.”

Ever since the time he was able to think in terms of the earth, man assumed it was flat. Here we have a belief that takes us back seven or eight millennia. When the International Committee of the
Geophysical Year announced that it intended to launch an artificial satellite, a German society very kindly advised it to abandon the project, which was doomed to failure since the earth is flat.

The Chaldeans believed in a cosmic cycle marked by the destruction of the earth by water and fire alternately. This belief was perpetuated through Greece and the alchemy of the Middle Ages, and it was promulgated again in the works of the famous contemporary hermetist Fulcanelli. Fulcanelli is the pseudonym of a mysterious hermetist who, between the two World Wars, published his fundamental works *The Mysteries of the Cathedrals* and *Philosophical Customs*. In the latter he confirms his belief in the Great Year, as we shall see in due course.

Men have always believed that catastrophes are caused by comets. When Dr. Velikovsky outlines his fantastic drama of the comets, for example, he is but perpetuating a tradition that in fact goes back to the earliest times. Even the hallucinations of Horbiger's cosmogony bear a strange resemblance to ancient Germanic and pre-Columbian beliefs. The fact should therefore be obvious that such a tradition is not the outcome of a few isolated works, but of a body of opinion deeply embedded in man's ideas of the universe.

It is obvious, then, that it would be wrong to view our history of fantastic earths as a mere museum containing strange and picturesque relics. Our present study is necessarily much more than that. It would be equally wrong to state flatly that such theories as geocentricity, the flat earth, the hollow earth, and so on, have nothing to do with real physical phenomena. The interest of such theories rests precisely in the rebellion of the human spirit against the facts. On the other hand, it can be asked quite justifiably whether other myths or fantastic hypotheses do not retain a part of reality. In this respect it is important to note the difference between having a vague intuition about a phenomenon and making a discovery by scientific methods.

For a long time, for example, man believed that everything that happened on earth was directed by the sun. He elevated the star of day to a more exalted position than his gods. Far from scorning a study of the "divinity of the sun", science has had to pay close attention to solar influences and the progress that has been made as
a result of space research allows that our planet lives “in” the sun, which makes its influence felt in the major as well as the minor aspects of our terrestrial life. Now while this does not necessarily prove that ancient civilization had an exact understanding of solar physics, it does suggest that it was not merely by chance that these civilizations attributed such an important role to the sun.

Man has an unquestionable talent for explaining certain phenomena. His power of perception, derived from his immediate contact with his surroundings, is essentially a quality of the non-civilized. And when unable to explain these phenomena—or even, very often, to describe them—he has transposed them into myths or legends. This is why such narratives sometimes contain—but not always, as is too often claimed—a somewhat vague hint of reality. It also explains why man has devised certain apocalyptic systems as well as his myths.

Let us say, then, that in our museum you will not find any major discoveries in the scientific sense of the term. Yet this does not preclude the possibility of finding definite associations or links between recurring intuitions and the results of the most recent scientific research. This is what we will be able to establish throughout this work.
The Mother Earth of the Ancients

If we happened to be thrown back in time by several millennia, how would the earth appear to us?

The relationships that formed between an emerging human race and the world around it took the form of dialogues and exchanges. This was entirely to be expected, since primitive man regarded himself as a child of the cosmos. Contrary to sexual instinct, the relationship between copulation and procreation was definitely not known to primitive man. Human consciousness was able to establish such a law only at a more advanced stage in its development. Before this discovery was made, the primitive mind believed that woman was fertilized by various natural forces, even by the earth in its entirety. All the husband did was legitimize the child. His paternity was only assumed, however, the real father being the cosmos. The child was conceived in nature, and subsequently developed in the womb of the earth. At the earliest stage, the fetus was introduced by some mysterious process into the mother’s womb where the pregnancy reached its fruition. The relationship between the husband and the wife was unimportant.

The Earth as Teacher

As an offspring of the earth, man was enveloped in its maternal presence. The mother spoke to her son through many manifestations: through her trees, her stones, and her brooks.

If a child’s fate was in question, people thought nothing of abandoning it to nature, by a riverbank, for example; his primeval mother would take care of him, and he might even have the opportunity to become a hero. Moses is just one example among many.
Throughout man’s slow evolutionary process, the earth has constantly maintained its role of teacher. In this process of man’s development, the discovery of agriculture marked the real beginning of civilization; agriculture, of course, is really dialogue with the earth.

Primitive thought was not deductive, but rather proceeded by analogies. It linked phenomena which resembled one another and imposed upon them a common explanation. Thus was born the traditional vision of the earth which, out of the deep past, comes down to us today in legends and superstitions that by now have lost their original significance.

In this way was developed the connection between the sowing of seeds and the sexual act, between germination and pregnancy. A farmer could not go about his business for very long without becoming aware of the laws of procreation. By becoming a farmer, primitive man grew to comprehend his role as a father.

Tutored by the earth, man began trying to explain the world by reversing the process of analogous reasoning. To start with, he extended the law of procreation to encompass all creation. Any creative act presupposed the principle that there had been a union of male and female. Everything in the world therefore assumed human and sexual connotations. The field automatically became the womb of mother earth. Yet it would be entirely erroneous to see anything more in this than a naïve attempt to explain a natural phenomenon. Man was not attempting to find a physical explanation for the phenomena he observed, but was rather imposing his own subjective experiences upon them. He found it necessary to seek in nature a certain stability, certain intuitions which he blended in with his own humanity. He created the world in his own image. With reference to the Aztec view of the world, Jacques Soustelle has written: “The Mexican image of the universe reflects the Mexican people and not the world.” (la Pensée cosmologique des anciens Mexicains).

Earth, then, was the primeval mother. Tellus-mater: this is one of the leitmotifs of the mythological universe. Primitive cosmogonies generally explained the creation of the world by the union of an earth goddess and a celestial god. Eventually a more complex
mythology evolved, but the goddess mother remained one of the most respected, if not one of the most revered, of all the divinities. We know of only one exception to this: that of ancient Egypt, which made Geb an earth god.

One eventual outcome of this was the refusal of a tribe in central India, the Baiga, to till the fields in order “not to rip the breast of mother earth with a plowshare”.

For certain pre-Columbian civilizations, mankind had its origins in four “womb-caverns” located in the bowels of the earth. This particular view stemmed from the fact that mythology saw in the earth not only the symbol of maternity, but also the actual body of the primeval mother. The planet was in effect a woman; thus caverns, wells, or river sources became her sexual organs. Linguistics are especially instructive on this subject. In Semitic language, Pāl means “source of a river” and, at the same time, “vagina”. In Sumerian, Buru has the double meaning of “river” and “vagina”.

If earth, then, was mother and primeval woman, one could well say from the other standpoint that woman became earth for man. This theme runs through all ancient traditions. In an Egyptian poem, a young girl, happy and in love, cries out, “I am the earth.” “Young girls carry their pastures within their own bodies”, says a French proverb. “Your women are as fields for you”, echoes the Koran. And when Demeter and Jason made love, it was in a furrow where wheat was growing.

Agriculture and sexuality were being constantly interwoven. Part of the Dionysian cult was the widespread practice of holding sexual orgies in fields in order to stimulate the earth’s fertility. The maternal influence of the earth could not be anything but beneficial, by the very fact of its being maternal. To regain health a sick person would stretch out on the ground so as to draw from the magical properties of the maternal breast. To surrender his last breath, the dying man was laid upon the earth in all his anguish, thus dying in the arms of his mother.

In Russia, disputes arising over land could be settled by an oath sworn with a piece of earth placed on the hand. It was assumed that the oath was inviolable: one surely could not lie with one’s own mother as witness.
PARTAKING OF THE EARTH

Ultimately, man partook directly of mother earth, rather than through her fruits. He did this in order to communicate more intimately with her and to fill himself with her beneficial powers.

Eating the earth is a universal custom. It seems that the practice was born in Asia some thousands of years ago. In India, small plates of “edible” earth are sold. In Java, people munch on small tablets of earth which have the power to keep the body slender. As a delicacy the Siamese crave a specially prepared form of earth. In Mexico, earth is sold in market places in the form of a volcanic cinder. Many earth eaters, however, derive their nourishment directly from the earth and want to absorb it as soon as they scoop it up as if afraid it might otherwise lose its magic power. Some fanatics even dig out earth from under their own houses at the risk of having it cave in. A complete report was made on earth eaters in the United States by the magazine *Fate*.

In general, it can be said that only a certain kind of earth is considered “edible”. In the United States, a sect of earth eaters was founded at the end of the last century by a William Windsor. This man claimed that illnesses peculiar to human beings arose from the fact that, unlike animals, they did not eat earth. His disciples dig the earth deep enough to uncover a particular mold which they recognize by its odour. These people claim that they draw from this substance a new, quasi-magical power which the earth hides within itself. Strange as it may seem, the practice of eating earth is apparently habit-forming. Despite the existence of medical symptoms giving warning of tuberculosis, gastrointestinal upsets and blood poisoning, these earth addicts swear that they cannot, live without it. They suffer from the lack of it exactly as a drug addict does.

THE EARTH GIVES BIRTH TO MINERALS

One day, man discovered on the earth’s surface a heavy pebble, black and shiny, which bore no resemblance to any other stones he had come across. This stone had some curious properties. When it was heated, for example, it became malleable; then when it
became cold again it assumed its original hardness. It was the ideal material for making a tool or a weapon.

Man naturally wondered where these mysterious stones came from, and the answer was furnished when he had occasion to see a meteor falling. The marvellous material came from the sky; it was divine.

The first metallurgy founded on this meteoric iron could hardly make such progress, however, since the raw material was really too scarce. Fortunately man discovered that the earth’s interior held metallic veins. Yet this discovery did not take away from the metal the divine character which man originally gave to it.

Among the metals found in the earth, there was one more perfect than all the other, which represented matter in its highest degree of perfection: gold. It is true that other noble metals existed, silver being one of them, but they were not perfect. And then there were others that seemed more common, which we call base—as if the family of metals had its own hierarchy. The conclusion was naturally drawn that there existed an evolution of metals similar to that of living things.

This evolution within the primeval mother, tantamount to a very long gestation period, allowed the metal to attain the adult stage: the state of gold. In this respect, Mircéa Eudiade has written: “Minerals grew in the womb of the earth mother more or less like embryos. Thus metallurgy assumed an obstetrical character.” A study of the myth of the earth, the mother of metals, was made by Mircéa Eudiade in the work Forgerons et Alchemistes. According to the myth, generally speaking, everything in the earth is alive but is in a state of gestation. This is obviously the case for plants. It is typical of this point of view that, above all, man found gold on, and not in the earth. A striking analogy can be made between the nugget of gold and the ripe plant leaving the earth. As one alchemist wrote: “What is a mine but a plant covered with earth?”

It was not enough, then, for the earth to nourish the vegetable and animal worlds out of its inexhaustible fertility: it worked ceaselessly. Bernard Palissy has written: “The earth is never idle. She renews and refashions whatever devours itself naturally within her. If she does not do it in one way, she will do it in
another. The result is that the exterior and interior of the earth are constantly and simultaneously at work producing.” Let us move forward several centuries now, until we find ourselves before the alchemist’s furnace.

For the alchemist, the destiny of man and that of the earth were inextricably intertwined, because the earth also has a destiny to fulfill in a spiritual sense. A bright star fallen into the shadows, the earth seeks redemption so as to return to its original state of light. In terms of a long operation in symbiosis with man, she will attain a state of perfection surpassing our sun itself, the perfection of human spirit adding itself to that of matter. There is, then, a total analogy between the destiny of the earth and that of humanity, which fell after the original sin and was redeemed by Christ. We must save the earth in the same way Christ saved us. We should prove our respect for it. “Help me and I will help you; deliver me and I will deliver you”, said the earth to the alchemist.

For the alchemist, metallic transmutations constituted a ritual, a sacrament, and not a series of chemical reactions. To find the philisopher’s stone was to accomplish the miracle of love, that of saving the earth and redeeming matter. “To make gold”, then, no longer has the meaning that the non-initiated would give it. Earth was not only a living reality; it was also a spiritual reality, and one did not make gold to amass a fortune any more than one produced children to sell them as slaves to increase one’s fortune.

A LIVING SPACE-TIME

Today, the earth seems to its inhabitants to be as neutral as a hotel room. It exercises no influences, either good or bad. Earthly space-time is the indifferent scene in which the human comedy is performed.

This conception of a neutral world, of empty time, of a humanity abandoned to itself in a universe exclusively physical and profane, was entirely foreign to primitive thought. For it, on the contrary, each place, each instant, had a “personality”, a “magic change” characteristic of it. Human action was inscribed in this setting, full, alive, heterogeneous. “Each place-instant
determines irrevocably all that which happens in it”, explains Jacques Soustelle about the Aztec world.

This heterogeneous space was organized generally around a given centre, a divine and mythical place, “the Centre of the World.” The Hindus have their Mount Méru, the Chaldeans, their Great Mountain, the Christians, their Golgotha, the Mohammedans, their Mecca, etc. . . . Thus, space took on a living presence which participates in the life of man. This added dimension had a favourable influence. For this, man had to act in keeping with a veritable “magic geography” of the world. The pre-Columbian civilizations pushed even further the mystery of these beliefs. The Aztec world, for instance, took the form of a cross. A divinity presided at each cardinal point. According to laws known by the priests, it gave out a power which could be either beneficial or harmful.

The general custom of pointing sanctuaries toward the East is also one application, among many others, of this belief.

In the same way, time did not unravel itself according to a uniform plan. Each of the instants which followed one another had its own essence and resembled neither the one that preceded it nor the one that followed it. Here again, there existed a potential force which varied constantly. In this personalization of time the Mayas attained a sort of paroxysm. Time, for them, far from being the abstract path of destiny, was only the manifestation in our world of a beyond peopled by creative or destructive divinities. Each segment of duration corresponded to the preponderance of one or the other of these gods. Thus, the day followed one another without resembling one another, as each one fell under a different influence.

THE NEW ASTROLOGY

This general belief in the heterogeneous nature of time pushed men to search for favourable future periods so as to profit from them with more certainty. The response was always sought in the skies.

Can one admit as proven a certain correspondence between observable reality and the beliefs of traditional astrology? One is
confronted with an apparently insoluble problem: how could a science based on an entirely false astronomical system lead to correct results?

Everything is unlikely in the traditional astrological explanations. How could they admit that bodies as different in their constitution and situation as the planets could exert the same influence? How could they believe that stars situated millions of light-years from us could exert any kind of influence on our earth? Only the nearby explosion of a gigantic supernova would be credited with having such a power. This hypothesis has indeed been advanced by the Soviet astronomer, Shklovsky. He affirms that he has identified supernova whose explosions brought about on earth the extermination of the fauna which characterized the end of the secondary era. But this event was not taken into consideration by the astrologers. In brief, no one can really take seriously the traditional explanations of astrology.

Let us suppose now that all astrology could be explained by a sun-earth interaction. Only a lucky coincidence would allow us to place it in relation to the apparent movement of the stars. Such is the hypothesis advanced by Michel Auphan, the inventor of a system which possesses, if nothing else, the advantage of coherence. Auphan proposes that the sun emits still unknown rays, called "odique waves". These rays, which obey the law of electromagnetism, penetrate the earth. The globe acts vis-à-vis this flux like an oscillating sphere bathing in a magnetic field.

The calculations of the reforming astrologer led him to believe that the influence of these rays depends on the position of the earth in its orbit. From this point of view, he distinguishes twelve sectors on the ecliptic which correspond to the famous twelve signs of the zodiac, but have nothing to do with them.

Man is equally affected by this ray. But he is principally penetrated by the flux which the earth gives out and not by that coming directly from the sun. The essence of the forces which determine us is found not in the stars, but very simply under our feet, in the heart of the earth.

1 It is to be noted that Auphan thinks that he has "re-found" astrology. For him, the formulators of astrology had to possess a knowledge of physics superior even to our own.
There we have the earth brought back to its dignified status of primeval mother, and a particularly abusive mother; never allowing her children to reach their majority, she controls them from birth until death. But our veritable tellus-mater has become a sort of gigantic emitter of waves, and her children obey her according to the laws of cybernetics. Poetry must certainly be the loser in this transition. . . .
3/The First Awareness

If one believes the history of science, the discovery of the earth really began with Copernicus. Until then, the insufficiency of technical methods and the absence of a true scientific spirit had allowed only a false, or very limited, knowledge of our planet.

The hermetic tradition, on the other hand, leads one to believe that from the farthest reaches of antiquity a whole line of initiated people possessed far more extensive knowledge. The history of the sciences as presently taught concerns only exoteric knowledge, forgetting that there presently exists and did exist an esoteric knowledge bearing on, among other things, the earth. What are we to believe? We should believe the facts, or as much as we can glean from those at our disposal.

A SURPLUS OF ENIGMAS

Numerous researchers, Abbé Moreux in particular, have maintained that in its mensurations, the pyramid of Cheops resulted from a science known only to the high priests of Egypt.

They have pointed out that its orientation to the north is as precise as that of the observatory in Paris, that the diagonals of the monument precisely match the Nile delta, and make the river a bisector, that the work is constructed at the point of encounter of the two most "terrestrial" meridians, that the primitive height was a millionth of the distance between the earth and the sun, etc. . . . Some of them even went so far as to affirm that the monument was conceived with, as a unit of measure, the "sacred" length of 2.085 feet, which is the ten-millionth of the polar terrestrial radius.

Almost unanimously, the scholars absolutely reject this hypothesis, which does seem very unlikely, to say the least, if only for the
fact that the Egyptians used a duodecimal arithmetic system rather than a decimal system.

**ANCIENT MAPS**

In 1929, an ancient map of America was discovered at Istanbul. An inscription in the margin explained that the document was the work of Piri Reis, grand admiral of the Turkish fleet, and that he had made it in 1513.

The author went on to explain that he had used information furnished by one of Columbus’s sailors, who had been taken prisoner in a battle, as well as by maps going back to Alexander the Great.

The scholars were astonished by the outline of the Brazilian and Argentinian coasts which Columbus had not explored. The map also depicted lands to the extreme south for which they could find no corresponding geographical location.

In the course of the years 1949–52, an international scientific expedition undertook to carry out a vast campaign of seismic research in the Antarctic. This operation aimed at determining the thickness of the ice cap and, by deduction, at establishing the configuration of the subjacent continental base. It was thus possible to establish a map of the Antartic such as it would appear if the ice cap were to melt.

During this time, an American explorer, Mallery, had, with the help of the hydrographic service of the United States Navy, redrawn Piri Reis’s map, using Mercator’s projection.

When they could finally compare the reconstructed map and the new map of the Antarctic, the evidence confronted them: the admiral of the Turkish fleet had drawn with precision one part of the coast of Antarctica (the Queen Maude area, in particular). Even better: since certain discrepancies between the two documents were visible, new seismic soundings were made. They proved that the ancient map was correct. The Antarctic was, in fact, being explored with ancient maps.

The discovery of Piri Reis’s map was accompanied by great publicity. Ataturk wanted to examine the document personally. From then on, scholars have kept it in their own possession. If
there were any falsification, it must have taken place before 1929. And no one at the time could have drawn the Queen Maude area, which by then was covered by two thousand metres of ice. The authenticity of the document cannot be doubted. It has even been recognized by the American Geographical Society and the Royal Geographical Society.

The incident of the Piri Reis map is not an isolated one. In fact, ancient Nordic maps, which show Greenland divided into three islands, have been found in an Icelandic cathedral. The seismic study of Greenland was undertaken by the French polar expeditions of Paul-Emile Victor. It confirmed that under the glacial cap Greenland was in reality composed of three separate islands whose outlines corresponded well with the drawings on the ancient documents.

What conclusions can be drawn from these facts? It is certain that some peoples possessing a high degree of civilization travelled around the globe before the existing polar caps were completely formed. This brings us at least five thousand years back and probably even further. It also proves that we are far from having examined all the knowledge of the past.

We could go on citing other similar facts: Plato’s allusion to America or the description of the satellites of Mars by Swift, 150 years before their discovery, for example. In America, still undecipherable inscriptions have been discovered, but the pre-Columbian civilizations did not know how to write. Mallery’s works are worth examining on this particular theme.

These facts are very significant when placed in their proper context. We conceive today only of knowledge which is open and exoteric. In the past, on the other hand, men of science attached a fundamental importance to esotericism. The uncontrolled diffusion of the different branches of knowledge was considered a real crime. In his Opus tertium, Roger Bacon wrote in this respect: “These cruel men, if they knew the secret, would make bad use of it and upset the world. I must not go against the will of God and against the interests of science. That is why I will not write these secrets in such a way that just anybody can understand them.” And Fulcanelli affirms in his les Demeures philosophales: “Exotericism has thrown the heart of man into a state of confusion.”
This denial of free access to knowledge was not due to the alchemists alone. Just about all civilizations have been guilty of this. Even in the Middle Ages, numerous corporations hid the secrets of their art jealously. The reasons behind this attitude were not only moral. They corresponded often to a will to conserve within a certain closed caste the monopoly of knowledge. The concealing of knowledge was one of the most effective means used by priests and scribes, or merchants, to resist the pressures of secular power and to conserve their autonomy. To divulge their knowledge would have been to place themselves at the mercy of those who controlled material forces. Thus, in a parallel course to the open advance of official science ran the occult sciences, using secret methods. Presumably, no one knew what was on the other side of the Atlantic, but regular and secret liaisons existed with America. Scientific or religious authorities taught about an earth which was flat and immobile, but it can be neither proved nor disproved that certain initiated men did not know of another earth, perhaps the real one.

This is evidently only a possibility, but the little that we do know of extinct civilizations forces us to be prudent. There are gaps of thousands of years in our knowledge of human history.

Given these conditions, can one with any certitude find traces of a knowledge which did not want to leave any? Let us keep in mind, then, the necessity for caution and not exclude the possibility that the ancients possessed an awareness, and particularly a geographical awareness, of much wider horizons than we might think.

THE FIRST THEORIES

The most ancient civilization known, that of the Sumerians, saw the earth as a gigantic mountain, surrounded by an enormous wall upon which the sky rested.

Heirs of the Sumerians, the Chaldeans, conserved pretty much the same earth. For them, the great Mountain was hollow and sheltered within its sides the kingdom of the dead. It was surrounded by the river Ocean, and on the other bank stood the walls which upheld the metallic dome of heaven. Earth and heaven
floated on the primordial Ocean. Celestial caverns held the upper waters from which came the rains. The sun travelled through the sky on a chariot.

Influenced by the location of their country stretched all along the Nile, the Egyptians thought of the world as a sort of chest, longer than it was wide, of which the earth formed the bottom and the sky the cover. Four mountains situated at four cardinal points upheld the sky, from which the stars hung like lanterns lighting the evening. A celestial river surrounded the world. Its regular tide carried on it the sacred bark by means of which the sun travelled, making the tour of the earth every twenty-four hours. Since it made one part of the trip behind the mountains, the earth was thus deprived of its light and plunged into the night. The celestial river poured into a fabled ocean occupying the heart of Africa. It has been established that such an inner sea actually did exist in a recent era. At the time when the ancient ancestors of the Egyptians lived, it could not have been anything more than an immense swamp, difficult to navigate because of its shallowness and innumerable isles. These characteristics would correspond well enough to the Egyptian conception of a mysterious sea which was forbidden to navigation. The Nile had its source in these mysterious waters.

The Chinese lived in an immense covered wagon. The earth constituted the floor of the wagon. As for China, its inhabitants saw themselves as living in the privileged situation of the “Empire of the Middle”. The terrestrial confines were limited by four immense oceans. The canopy had no less than nine layers, one on top of the other, which represented the same number of skies. This complex heaven covered the earth by means of eight pillars. Unfortunately, one of the supports had collapsed after a cataclysm, and from then on, the sky was lopsided. The polar star—the true centre of the sky—was transported for life toward the north. The earth itself leaned toward the southeast. This myth was, from all evidence, inspired by the general direction of the river network in China.

We see that in all these systems essentially scientific preoccupations held second place. This is even more readily evident when the cosmogonies or explanations of natural phenomena are
studied. The creation of the universe was imputed to the union of a celestial god and an earthly goddess, to a celestial battle, to the hatching of a cosmic egg, or to other events even more fantastic. The winds, rain, germination, and extremes of temperature were all attributed to divine intervention. The entire course of nature was for better or worse tied up in the game of supernatural forces; when a phenomenon appeared to be incomprehensible, they did not try to study it in depth; rather they complicated their mythology some more to arrive at an explanation.

SCIENCE BEGAN AT MILETUS

"The gods amount to nothing!" The man who was the first to observe nature and have this insight gave a push to the progress of mankind as decisive as that of the discovery of fire or of agriculture. At school, we all learn this hero's name: Thales of Miletus. To this name has been attributed simply the discovery of a geometric theorem, and history is guilty of great ingratitude for this. Thales of Miletus, an obscure geometer, was in fact the point of departure for our whole civilization. The most ancient and the most celebrated of the Seven Sages lived approximately between 640 and 548 B.C. It is thought that he had some contact with the Egyptians and the Chaldeans. He would have been the one to take from the latter the necessary knowledge which allowed him in 585 B.C. to predict for the first time in the Greek world and eclipse of the sun. His prediction of this eclipse, which plunged into darkness the battlefield on which the Persians and Lydians were fighting, made him famous, but the life story of this man is shrouded in an aura of legend which is difficult to dissipate.

Certainly the situation at Miletus in the middle of the first millennium B.C. called for an intellectual revolution. The Greek colony, a very active commercial centre, was the crossroads of all civilizations, beliefs, and religions. This confrontation was necessarily going to provoke scepticism and cast into doubt an entire system of thought which gave several different explanations for the same phenomenon. The time was ripe; all that was needed was the right man. He turned out to be a middle-class bourgeois,
who, as far as we are concerned, worked out an erroneous system from A to Z, or rather, from alpha to omega.

Thales tried to explain the world in terms of a physical unity, not a supernatural one. He found it in water. For Thales, the earth, the sky, the stars, and of course the oceans, all consisted of water in different forms. He saw the earth as a more or less convex disk, floating on the surface of a gigantic ocean.

This theory holds little attraction for us. One point is worth retaining, however: the forces which make themselves felt in nature are produced by physical mechanisms, and not by the intervention of deities. Thales was nothing less than a materialist. He leaned a little toward pantheism, however, by seeing in physical phenomena the manifestation of a spirit which was in everything.

The flame kindled by Thales was not extinguished, thanks to his disciple, Anaximander. Friend and disciple of Thales, Anaximander lived in Miletus from 610 to 547 B.C. To him is attributed the invention of the gnomon as well as the drawing of the first map of the world. Through his efforts, decisive progress was made in man’s knowledge of the earth. He did this by projecting it into space.

In practice, how did the earth look to Anaximander? It took the form of a cylinder, something like a drum, three times as wide as it was high. Only the upper part was inhabited. This earth was isolated in the middle of a sphere, held up only by whirlpools of air, and it returned periodically into a state of undifferentiated chaos.

The idea of an earth isolated in space was not accepted. At this time, a philosopher of the Ionian school returned to the idea of the earth as a celestial vault. This was the successor and near homonym of Anaximander, Anaximines, who was born between 550 and 500 B.C.

He kept the earth’s cylindrical form but had it float on a layer of dense air. He also sought in the world a primordial element and found it in air. In sum, our earth was only a bubble of air or, more exactly, a drum. Periodically the world returned to its primordial gaseous state to be reborn, following the cyclic law of becoming.
While thinkers at the Ionian school were reasoning in this way about the earth as a drum, the sceptics at Elea deemed it wiser to hold to the flat earth theory. One of the most colourful of the Eleans was Xenophon of Colophon. He seems to have been a sort of troubador of ancient times who sang legends in public places; he is said to have felt deep scepticism as far as mythology went. He considered the earth as a plateau stretching out infinitely. According to certain versions of his belief, he thought that different suns lit up this limitless stretch in different places; according to other versions, he believed that the sun moved parallel to the earth, its distance at the horizon giving the impression that it was setting.

Not long afterward, Empedocles explained all cosmic history by means of a battle between two principal antagonists: Love and Hate. The life of Empedocles, even though embellished by his biographers, seems to have been an extraordinary one. Possessing an encyclopedic knowledge as did all the great thinkers of his age, he was interested particularly in medicine and also, it seems, in magic as well. Spectacular results in this area have been attributed to him. Wherever he travelled, sick people rushed to him in the hope of a miraculous cure. He himself tells us that he was honoured as a god. History also tells us that he refused the throne that was offered to him. It seems most likely that he met his death at the crater of Mount Etna. According to some, he fell into the burning abyss while trying to study it too closely, but legend tells us that in trying to pass himself off as a god, he chose this form of suicide so that the people, not being able to find his body, would think that he had returned to Olympus.

Empedocles taught that the world was composed of four elements: water, earth, air, and fire, which have a natural tendency to keep themselves apart. There existed a principle, Love, which tried to unite them, while the antagonist principle, Hate, tried to separate them.

The universe, or Sphaïros, was closed, sealed like an egg. Love and Hate were engaged in a constant cyclic combat. At one time, Love alone reigned; Hate was thrown out of the universe. This dictatorship of Love was not a good thing, because the elements became too intermingled. Sphaïros was filled with a homogeneous,
shapeless matter, similar to the undifferentiated chaos of Anaximander’s. In time, however, Hate attacked and invaded the world. Because of his impetus, the elements began to separate. The universe took form; this is its present condition, but this condition is unstable. Hate will triumph and force Love to flee. Thus, the elements will be completely separated and spread out in concentric layers isolated by the strata of Hate. At this point, Love will launch a counterattack and triumph. A new cycle will begin to repeat again the same battles and the same turns of fortune.

Love, Hate: this is a strange philosophy of nature. It seems to belong more to the realm of metaphysics. The theories of Empedocles bear the influence of a very strange personage who revolutionized all of Greek thought: Pythagoras. Pythagoras is much more than merely the person who invented a theorem or who founded a vegetarian sect. Unfortunately, we know all too much about him, yet paradoxically, not enough. If one believes certain historians, he was the companion of Buddha and of Zoroaster. These three wise men, it is held, divided the world up among themselves. Others see in this forefather of philosophy nothing but a Sicilian politician. And finally, the most sceptical maintain that if the Pythagoreans really did exist, Pythagoras himself was an entirely fictitious person. Today, it is just about impossible to establish the truth.

We will speak then of Pythagoras, bearing this in mind, and focusing our attention essentially on the Pythagoreans. These men grouped themselves into schools which took on the aspect of esoteric sects, whose knowledge was at the same time occult and anonymous.

The gist of Pythagorean thought can be condensed to one word: “Kosmos”. Before Pythagoras, this word signified “order”, or “harmony”. For him, however, it took on the meaning of “universe.” The world was harmony. It materialized the sacred dance of the numbers, because the supreme value and the principle of all harmony was the number. The discovery of irrational numbers was a real coup for the Pythagoreans. For them, all the natural relations were expressed by rational numbers. The Pythagorean legend has it that the gods condemned to death by drowning
in a shipwreck the man who had revealed this knowledge reserved for the gods. Arithmetic became two kinds of philosophy; esthetic and ethical. Truth was hidden in numbers; it was by studying their combinations that one could eventually uncover it. So it was necessary to work with numbers, find their meanings, their affinities, and their relationships. According to their arithmetic properties, one could deduce their value and from it understand the world, where all numbers in their intimate relationships would be found. This is certainly a strange scientific method. But strangest of all was that this idealism was going to have a decisive influence on man’s knowledge of the earth, for the Pythagoreans discovered that the earth is round.

We do not know for sure just who discovered this. Legend, of course, attributes it to Pythagoras, but there are many reasons for believing that this discovery goes back to Parmenides. Parmenides, at first a member of the Pythagorean sect, became a member of its rival school at Elea and a disciple of the sceptic, Zeno.

The Pythagoreans still held out for the earth as a sphere. The explanation that they gave for this theory led people to wonder if they had not received this knowledge from an ulterior source. The earth is round, they explained, because the sphere is the most perfect form, the one which is always, at any point, similar to itself. Yet, with this method, they could well have made of our planet a pyramid or a cube. The spherical nature of the earth, then, must have been discovered by an accident.

To the globe the Sicilian wise men gave a mysterious sister: the anti-earth. This strange cosmogonic system was described by Philolaüs. But here again, it is likely that even he was only revealing the Pythagorean cosmogenies.

The anti-earth was an unknown star which circled around and close to the central fire. The earth also described an orbit, but at a greater distance from the incandescent fire which was situated in the middle of the universe and which was not the sun, but the dwelling place of Zeus. Since the earth did not turn on itself, it always faced it from the same angle. The hemisphere which looked onto the divine furnace was torrid and uninhabited. People lived only on the other side of the globe, therefore they could never see either the central fire or the anti-earth. Thus, the
Pythagoreans had no need for physical proofs to affirm the reality of the phenomenon. The ideas of the Pythagoreans constitute a strange mixture of speculative a priori thinking and of observation, indeed of experimentation. They took into account what existed only insofar as to work it into their idealistic system. As far as the anti-earth goes, it is believed that it was created entirely in order to arrive at the number ten determined in advance, because of its sacred character, as being that of the celestial bodies. This manner of thinking nearly stopped the Pythagoreans from looking for any physical explanations of the various phenomena. "What stands out in primitive and middle Pythagorean cosmology is the absence of any notion of causality." (C. Mugler, Devenir cyclique et Pluralité des mondes, Paris, 1953.)

The Pythagoreans believed that the moon, the sun, and the planets described orbits each at a farther distance from the centre fire. Without going into the details of this rather astonishing system, let us merely keep in mind the considerable progress which it brought about. The earth was no longer the centre of the world, but a star like the others, endowed with its own motion.

The spherical nature of the earth came to be generally accepted in the ancient world, but its situation and its movement in the too arbitrary system of the Pythagoreans was not accepted. A disciple of Plato—who, like Aristotle, had returned to a geocentric belief—Eudoxus of Cnidus, explained the apparent movement of the stars by means of a series of spheres all centred around the earth. He needed no less than twenty-seven spheres to arrange his celestial mechanism. Aristotle took up the system and "perfected" it by bringing the number of spheres up to fifty-five.

While Aristotle lost himself thus in all these celestial spheres, his contemporary, Heraclides Ponticus, discovered the daily rotation of the earth upon itself. We should be cautious when we speak of a discovery. In effect, the educated people of that age, attracted by the Aristotelian spheres, rejected the idea. For mankind, the rotation of the earth upon itself would not be discovered until Copernicus. Heraclides maintained his geocentric theory, but he also held that Venus turned around the sun, which was the first step toward the acceptance of total heliocentricity.
The astronomers, for all this, were not satisfied with Aristotle's theories, which could not, in particular, explain the apparent movement of Venus. So they returned to envisaging the possibility that the stars described orbits which were not earth-centred. This system, which Apollonius in particular used, placed our globe in the centre of the orbit described by the sun, but outside the orbits of Mercury and Venus and inside those of other planets. Celestial spheres, excentric circles . . . toward the end of the fourth century B.C., everything was in a turmoil.

At this point a curious astronomer, Aristarchus of Samos, came up with the most fantastic hypothesis of all. Quite fortunately, all of the important people of the time imposed a harsh silence on this eccentric, who risked confusing everything with his preposterous ideas. Just what did this astronomer have to say? The earth is a planet like the others, which takes one year to turn around the sun. Besides this, it completes a rotational movement on itself daily. The moon revolves around the earth.

These ideas were not only absurd—which Archimedes in particular proved brilliantly—but they were blasphemous as well. The earth, dwelling-place of the gods, could never be considered just another planet; furthermore, to pretend that Zeus turned around like a top was a pure and simple sacrilege. People considered putting this impious man to death. It was finally decided to judge him mad rather than sacrilegious and he was told to keep quiet and was eventually forgotten.

Truth had lost a battle. It was to lose many more before finally triumphing.

After Aristarchus, the astronomers gleefully plunged back into the subtlety or error. Hipparchus complicated just a bit more the system of eccentric circles. Then, in the second century B.C., the Ptolemaic system came into being. Never before had a theory so entirely wrong held so much authority among the scholars. With this Alexandrian astronomer, the dictatorship of error planted itself firmly in the scholarly world. The earth found itself so solidly anchored to the centre of the universe that it would take fifteen centuries to dislodge it.

But the worst thing man did was to renounce the most important heritage of antiquity: the spherical nature of the earth. This
hypothesis, even though supported by Aristotle, seemed incompatible with the scriptures. Saint Augustine preferred to return to the flat earth theory, which was less troubling for man. Only a chosen few knew the real shape of the planet.

In the sixth century, the monk Kosmas proposed a particularly typical version of the current run of accepted ideas. For this scrupulously orthodox man, to describe the earth meant introducing the setting of the Bible. He laid down, then, as a postulate, that the world could know of having no other form than that of the tabernacle of Moses. In effect, this yields a flat earth surrounded by a mysterious ocean. On the other side of the waters lay unknown regions which served as supports for the celestial vault. Only the central part was inhabited by modern man.

Finally Copernicus came... but by then man had definitely acquired a taste for speculating about his planet, and the abundance of fantastic worlds was not to cease with the onset of truth; far from it.
4 | The Opponents of Galileo

Who can fail to be moved, imagining the old Galileo, crushed by the forces of error, but still striking the earth with his heel: *E pur si muove!*

Many men have known the frustration of despair since Galileo's time, precisely because of this planet which turns without seeming to. From the 22nd of June, 1633, on, there would always be heretics to cry, "But it does not turn". They were not forced to their knees in a church or thrown in prison or threatened with death at the stake; they were ignored. And they died one after the other, taking to the grave this "truth" which mankind did not want.

**The Sentry's Pentecost**

Imagine a winter's night during World War I. A sentry was on duty. Like all sentries of the world, the soldier was bored; he kicked the ground, looked at the sky ... and, suddenly he understood. Henri Barthélémy understood that the world was mistaken. Up there everything turned; down here, nothing turned. Certain of having good sense and probability on his side, Barthélémy inveighed, taunted, railed, and fulminated. He began pleading with astronomers that they show their good faith by abandoning their erroneous deductions and by following him on the correct path. He assured them that he would be their guide.

And the guide revealed first of all that “the earth is the centre of the universe”. In fact that was the title of the work he published with Jean Decois in 1933.

Secondly, it was immobile. The erroneous reasonings of the past had come to an end, as well as man's concept of the universe as being fantastically big. In anger, this astronomer remeasured the

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distance between the earth and the sun, and found that it was between 19,766 and 4,053 miles. This seemed more reasonable.

The enormous sun also had a frightening aspect. There was good reason to believe that here, too, the scholars had been mistaken in their calculations. Evidently, simple good sense proved this: “When during an eclipse the moon passes opposite the sun, the latter is completely hidden. It can be deducted that the two discs have roughly equivalent dimensions, about 130 miles.”

And then, there was the disturbing picture of this planet that leans. Barthélémy wanted to set it upright. “The tilting of the axis of the poles makes no sense,” he said. As for the stars, they were bubbles of gas.

It was quite simple. The sun turned around the earth, describing a spiral as it went. “Thus the circles of solar rotation move in the course of the year between the two tropics. It is this oscillation which brings about the seasons.”

The moon revolves around the earth in twenty-four hours and fifty-two minutes. Thus, it loses time every day and at the end of twenty-eight days seems to have made a complete revolution. To end with, Barthélémy wondered if the earth “could give an image of the phenomenon of blood circulation” and if a gigantic heart was not hidden somewhere in the centre of the globe. It was something “to be studied”.

THE OLD LADY AND THE EARTH

The widow Madame Pierrel was a martyr of the earth, although she did not have the buoyant optimism of Barthélémy in shaking up official science. When she published her last work in 1926, she was seventy-five years old. For twenty-five years she had hounded Camille Flammarion and the Astronomical Society of France to make them admit that the earth did not turn around the sun.

She believed that as soon as she spoke, the astronomers understood that she was right and that all their ideas were wrong. But they did not want to pass judgment on themselves and lose face by acknowledging the falsity of the Copernican system. So they agreed among themselves to smother her discovery.

Not only did they not want to hear about it, but they even
wanted to steal it from her. Thus, M. Poincaré wrote that “no mathematical proof of the earth’s movement exists” and that “the earth’s rotation around the sun has not been scientifically proven”.

The manoeuvre was obvious. Official science was tossing up a test balloon. They let it be known that they had doubts about the Copernican system. Tomorrow the astronomers would say that they had discovered a new system and would attribute to themselves the discovery of her system.

This was too much. The old woman published a new exposé of her theories to cut the ground from under the feet of the usurpers. “Immediately afterwards,” she noted, “M. Poincaré retracted.” These statements of Poincaré’s are perfectly authentic. The mathematician simply wanted to show what caution had to be shown in bringing forth a scientific hypothesis. But Drumont, the fiery polemicist of anti-Semitism, heard of this and pretended to see in it a refutation of the Copernican system which was more or less coloured by Judaism. The conservative and national press played up the affair until Henri Poincaré published a scathing and flat denial, affirming that he had never doubted the rotation of the earth.

Unsuccessful at stealing her system, the astronomers decided to smother it, she believed. They refused to receive her or to answer her. The press would have nothing to do with her theories—in short, there was a general conspiracy of silence.

When the old woman launched her last appeal, she could no longer control her indignation: “Through my voice astronomy calls out in distress to the four points of earth, and this cry can be summed up briefly in these words of accusation: Error! Lie! Mystification! Fraud!”

For Madame Pierrel, the earth was the centre of the world, an earth which turned and which tilted. Its axis or rotation made an angle of 23° 27’ with the axis of the world, which naturally passed through its centre. The celestial sphere was organized around this axis. On this sphere the sun was located at the Tropic of Cancer. It was this off-position that made the earth tilt. In the centre of this sphere the earth turned upon itself. This rotation was accompanied by a revolutionary movement around the axis of the world. Thus,
it leaned in relation to this axis, sometimes to one side, sometimes to the other. The terrestrial axis of rotation described, then, an immense cone with an opening of 46° 54′ centred on the axis of the world. A shift between the rotation of the earth upon itself and around this axis provoked the apparent movement of the stars and the organization of the seasons.

THE STRANGE SYSTEM OF THE PEASANT POET

Ten years ago, a self-taught and eccentric Italian poet called Silvio Corradi undertook a study of this terrestrial Sphinx.

An astute researcher, Corradi was first struck by the immobility of the Polar star in a sky where all else moved. Going from this verification, Corradi reconstructed the world. In the centre was the un-moving sun. As for the earth, everything happened as if it were suspended at the extremity of a pendulum attached to the Polar star. At the base of this immense, imaginary swing the planet executed a double rotation. It turned upon itself in twenty-four hours, but besides this, its axis described in one year a gigantic cone having the Polar star as its zenith, as well as an opening of 47°. The sun was not inside, but outside this cone. The earth moved in front of the sun and not around it. In its movements throughout the year, its orientation with regard to the stars varied constantly, resulting in the seasons. Each planet thus described its own small revolution in a corner of the sky. Corradi found his system “so marvellously extraordinary” that he saw in it a proof of “the infinite wisdom of God”.

POLYTECHNIC AGAINST EINSTEIN

What arguments would it take today to provoke a polytechnician to refute the earth’s rotation?

To understand this, we have to go back some eighty years. In 1881, the American physicist, Michelson, perfected an optical apparatus meant to prove the rotation of the earth around the sun. Thanks to the phenomenon of interference, he was able to place in evidence differences in speed twenty times less than that which the rotation of the earth was supposed to provoke between the
luminous wires passing through his apparatus. He was thus assured that the experiment would establish in approveable manner the movement of our planet in its orbit. Michelson tried the experiment and to the amazement of scholars all over the world, he showed that everything happened as if the earth were immobile. Verifications were made; the experiment was repeated every six months; they went so far as to repeat it in a stratospheric balloon; they perfected the system by heightening its precision, but to no avail. They came up with no evidence that the earth turned.

This stalemate plunged physics into a crisis which Einstein solved in 1905 with his theory of relativity. Responding to the question of the truth of relativity, Couder writes: “The only correct response that can be made is the following one: relativity, at the present moment, explains a great number of phenomena and explains them better than all previous theories.”

Michelson’s experiment could not succeed, Einstein explained, because the speed of light is a limited speed to which no other can be added. But two polytechnicians refused outright to accept Einstein’s explanation. The dissidents asked that good sense be the judge of the situation. An experiment was attempted to certify the rotation of the earth; it failed, so it was concluded that common sense told the truth: the earth does not turn.

The first polytechnician to launch the attack in 1934, Gustave Plaisant, saw in relativity a “Germanic philosophy”, a gigantic conspiracy of evil destined to make France, normally a country of common sense, lose its soul.

The plan was clear-cut. Thrust man into a fantastic and incomprehensible world; in this absurd and terrifying universe, he loses all confidence in his common sense. Doubt and anguish seize his soul, he renounces the faith of his fathers, and is consequently damned. On an earth that turned, Plaisant could no longer believe in anything and he certainly wanted to keep his faith.

Plaisant would have excommunicated the Relativists. In any case, they were without a doubt in a state of sin. “Before Copernicus and Galileo,” he concluded, “an admirable unity prevailed in philosophy. From this point on, science no longer allows a satisfactory explanation of the universe to be given.” Worst of all was the fact that this reactionary polytechnician was perfectly
correct since every discovery merely reveals our ignorance to ourselves.

What M. Ollivier wanted, in a very recent work, was also “to try to reconcile physics and common sense.” (Physique moderne et réalité, Paris, 1962.) Relativity, “sophisticated and contradictory,” was never anything but an “escape hatch” for refusing to admit the immobility of the earth. In fact, the earth, life, and man were unique and privileged phenomena in the universe, which “was made for man and not for itself”. It was a question once more of finding a “reassuring system. From the very outset, the dizzying picture of a plurality of words was rejected by Ollivier. The earth was the only home of the children of God because the stars, of which nothing was known, were without a doubt mere luminous phenomena. Ollivier reconstructed the world using matter as a starting point. The first reality was uninterrupted “substance” which became matter when it came into contact with light. Light was at the source of the world: it created matter. Between the two realities, matter and substance, existed “an actual correspondence, very intimate and one of the most precise”, a constant resonance. By absorbing the light, there formed denser media, which were, in fact, the atomic nuclei.

“Where would sense and the physical impact of such a resonance between light and matter find their fulfillment, if not in a metaphysical ideal?” asked the polytechnician, creating, as had the Greek idealists, the physics for his metaphysics.

Ollivier concluded: “The world of the ancients is being reborn before our very eyes. Furthermore, if the commonplace and secular common sense of the Middle Ages were abandoned, how could we construct a real, solid astronomy … without having the least idea of what gravity is?”

WRONG WAY ON A ONE WAY STREET

To stop the earth was already an extremely difficult thing to try; but to put it into reverse motion would seem entirely out of the question. Fortunately, no task was too formidable for our conquerors of different earths.

It was a respectable Berliner, Valentin Herz, who succeeded in
this miracle, which proved to be the most astonishing of the anti-Copernican era. For thirty years, the amateur astronomer had pursued his studies. About fifteen years ago, he finally succeeded in perfecting his system.

The earth, he explained, does not turn toward the east, but toward the west. Furthermore, it does not complete its revolution in twenty-four hours, but in twenty-eight days.

This was obviously unexpected. The alternation of days and nights could easily have seemed to be a rather well established phenomenon. Reasoning in this way, man has been the victim of an illusion. What he calls the sun is in reality merely the projection upon atmospheric gases of the true sun. This latter has its place not in the sky but somewhere above the South Pole. From there, it shines down on our atmosphere, which in turn acts to us like a mirror. This beacon, the particular star of the day, sweeps the horizon in twenty-four hours. The alternation of light and dark has nothing to do with the terrestrial rotation, but depends on that of the sun.

The earth, not having the same inertia as liquids and gases, moves in its orbit faster than the atmosphere and the oceans. Thus, currents form which seem to move in a direction opposite to that of the planet’s rotation; that is, these currents always flow eastward. There is no room for doubt, then, that the earth turns toward the west.
“Doctor, please examine me. They say I’m going crazy.”
“For Heaven’s sake, why?”
“Because I know that the earth is a live animal.”

This conversation is not at all fictitious. It actually took place in the beginning of the nineteenth century, and was related by the patient himself: Chevrel-Dessaudrais.

A government official at Montauban, Chevrel-Dessaudrais published in 1805, a work entitled The Key to Nature’s Phenomena or The Living Earth, which earned him an established reputation as a lunatic.

In his book, the official explained that our globe was a huge animal on whose back we live as parasites, as lice on a skull. In truth, he never found out exactly if one or two animals were involved. In effect, his speculations led him to believe that the new world was the female of the ancient.

One or two animals, the fact remained that our earth was alive. It did not travel in its orbit because of universal gravitation, but because of its own movement, like that of an animated being: it walked in the sky. Now it may well be argued that an animal needs its sleep, and the earth never stops its orbital movement. According to Chevrel-Dessaudrais, the earth did in fact sleep during the winter months. Since it continued to move, however, only one explanation was possible: the earth walked in its sleep.

The animated nature of the earth was proved by life itself. To support life, the earth had to be alive, since nothing grew on a dead body. “If life was not common to both earth and animals, where would the remarkable similarity between the growth of the grass in the fields and that of our beard come from?”

Further proof that our planet is alive lay in the fact that it could be seen breathing. Swamps could not be explained otherwise.
Extremely swampy areas corresponded to the chests of animals. As for what the earth fed on, the official claimed that it ate what fish ate: bodies suspended in the waters of the sea. Our wretched earth could even fall sick and be seized by convulsions; thus, earthquakes were explained. As for the animal’s limbs, these could be easily folded under it. They were therefore immersed in the depths of the oceans. Sometimes the animal stirred and moved around: in this way, great floods and violent currents were created. In short, the earth was alive.

THE GEON IS A LIVING CELL

Our government official was quite wrong in worrying about his mental health. If everyone who believed in such a theory had to undergo psychiatric examination, quite a few people would be in the waiting room, in particular, Kepler, the German naturalist Fechner, his compatriots Wilhelm Preyer and Doctor G. Heymans, the American Strong, etc. This theme is one of the great sources of inspiration for science fiction. The authors have subdued the earth, tended it, tamed it, and finally killed it off, as in Wailly’s novel, Murderer of the Globe. In this work we have a strange scholar (the heroes are always strange scholars) who has discovered a place where the skin of the animal-earth is particularly thin. Blazing a trail for himself into the animal’s flesh, he ends up by coming across one of its vital organs. Now the scientist hates the earth and decides to take his revenge on mankind by killing the earth... There is also Professor Challenger who, at the same time that the Russians are preparing to do it, pierces the hide of the animal-earth, inflicting a cruel puncture which makes it howl with pain (When the Earth Howled by Conan Doyle).

Life has been attributed to the earth under all sorts of different forms; but the geon conjured up by Dr. Jaworsky represents without a doubt the most coherent contribution in this respect. This theory was defended in The Geon or The Living Earth, published in 1937. Dr. Jaworsky imagined a biological cosmogony in which mattron on all levels was endowed with life. Thus, comets were “cosmic spermatozoa” which sowed the clouds with cosmic dust. Thus new living organisms were born: these were
planetary systems and galaxies. His theory can be compared to the views of Svante Arrhenius and his idea of panspermism, by which life is brought from one world to another.

The geon was the living ensemble formed by the earth, the hydrosphere, the atmosphere, vegetables, animals, and men. From this point of view we do not live on, but in the earth. Imagine a living cell with a nucleus, a nuclear membrane, all surrounded by protoplasm, and you have a scale model of the geon.

The terrestrial globe constitutes the nucleus with the earth’s crust as membrane, while the atmosphere and the hydrosphere constitute the protoplasm. The geon’s heart lies at the core of the earth. From it circulate vast currents of heat which are nothing else but the circulation of the blood. The discharge of lava are haemorrhages; hardened lava is coagulated blood; rocks, mountains, and stones constitute the skeleton; the hydrosphere is the lymphatic system; and floods are oedema. The ensemble of this organism possesses a physiology entirely biological. In winter, the earth sleeps, and its temperature drops, just as ours does.

And where do human beings fit into the ensemble? Each individual is only one of the neural cells of the terrestrial brain. Our role could be compared to that of the mitochondria that can be seen evolving around the nucleus in living cells. Dr. Jaworsky noticed in this respect that in the human brain the language centre is situated in the left hemisphere. From this he drew a parallel development of human intelligence and of language in Eurasia, which would be the “centre of Brocca” of the geon.

It is common knowledge that a living organism is born and eats. Dr. Jaworsky used the rays of the sun to feed his animal-earth; as for the geon’s birth, that was easily reconstituted. When the earth lived in its embryonic state, it was enveloped in a protective and nourishing mass. This role of protector and nourisher was fulfilled by the moon, which served also as a link between the sun-father and the embryo-earth. Our satellite emitted a warm and nourishing atmosphere which permitted the geon to form, little by little, throughout the course of what we now call the geological eras. Then, at the end of the tertiary period, the infant-earth, fully formed, was finally ejected into the cosmos, while the moon, a
dead placenta, was rejected. As a newborn child who passes from the warmth of the maternal womb to the lower temperature of the world, the earth underwent the cold period of the great glaciers. But it learned to form its own heat by itself. Today, measured by its own life span, the geon remains a very young being. Dr. Jaworsky estimated that it was seventeen years old. Barring, accidents, then, our earth will not die for quite some time yet.

THE EARTH IS HOLLOW

It was not an enlightened “wizard” who came up with the “scientific” theory of an earth which is hollow and inhabited inside. The man who did this was in fact one of the greatest astronomers of all time, the first to set up a catalogue of the southern stars, who demonstrated the correct movement of the stars, who observed and announced for the first time the return of a comet, and who was the author of the first studies of the variations of the earth’s magnetic field. His name is Edmund Halley. He imagined an earth which looked something like those Russian wooden dolls that fit inside one another. If the whole thing were taken apart, it would reveal in the centre a solid ball about the size of Mercury.

This ball was fixed in a kind of shell. There was a second sphere covering this, and finally there was the third, which is the one we live on. Between these spheres was an atmosphere making life possible on each one of them. Halley figured that the absence of the sun could be compensated for by either each atmosphere’s particular luminescence, or by the bright light of the concave inner walls which could be covered with incandescent material, like the sun itself. Due to this system, Halley offered in 1776 an explanation for the phenomenon of the aurora borealis. The flattening of the globe at the poles proved, according to him, that the earth’s crust was thinner at these points, thus becoming transparent so that the light from the interior world could pass through it.

Indeed, thought Halley, it would have been a great waste on the part of the Creator to have such a wealth of material serve only as a support for our world. The arrangement that he had in mind corresponded quite simply, he said, to a rational use of this space,
similar to that which prompts men to build houses several stories high.

One might justifiably ask how it was possible for such a great scholar to become involved in such a theory. Most surprising of all is that he was led to it by the most serious kind of scientific thinking. He had noticed that the earth’s magnetic field was in ceaseless motion. He thought that this stemmed from the fact that the different terrestrial spheres did not turn at exactly the same speeds, a hypothesis which brings to mind one of the more recent hypotheses proposed by the geomagneticians. (See the chapter on magnetism.)

At the beginning of the nineteenth century, the members of the American Congress, together with scholars from all over the world, received the following circular letter:

St. Louis, Missouri Territory, North America
April 10, 1818
To the entire world:

I declare that the earth is hollow and inhabited in its interior, that it contains several solid concentric spheres, placed one inside the other, and that it has an opening at the pole from twelve to sixteen degrees.

I am taking it upon myself to demonstrate the reality of what I have stated and am ready to explore the earth’s interior if the world will accept my request to help me in my enterprise.

Jno. Cleves Symnes, of Ohio
Infantry Captain, retired

For Symnes, the earth contained five successive spheres, and life was equally possible on both sides of all of them. Thus, there were beings who lived on the concave walls of these interior worlds. The most original aspect of this theory, however, lay in its famous polar “openings”. According to the retired captain, by going directly north or south, one could ultimately penetrate the earth’s interior. Symnes finally decided to undertake the adventure and sent out an appeal to one hundred “brave companions” capable of accompanying him to Siberia.

All that remained was to descend into the hole. The captain
launched a round of conferences to stir up public interest and obtain backing. A draft bill was even submitted to Congress to provide Symmes with the necessary backing for his expedition. He got twenty-five representatives to vote for him. . . .

Still another century went by, and in 1920 the hollow earth theory had another burst of popularity, thanks to another American, Marshall B. Gardner. Gardner’s theory was noticeably different from Symmes’s, which incidentally, he treated rather harshly. The new champion of the hollow earth theory needed no less than 450 pages of “proofs” to back up his statements.

The new hollow earth had the appearance of a sphere, 750 miles in diameter. It was pierced at the two extremities by two openings. At the centre of this interior world a sun 560 miles wide shone permanently. At times, its light escaped through the polar openings, causing the aurora borealis. The inner walls of the sphere held life as did those on the outside. Between the two worlds, communication was made possible by means of the polar openings. Already on several occasions, live specimens had made the trip from one side to the other.

The Eskimos, for example, were originally from the earth’s interior, but they stopped their migration at the edge of the polar opening. Sometimes this kind of adventure ended up badly. Thus the mammoths, used to the perpetual heat of the interior sun, were suddenly trapped by the Siberian cold and frozen when they arrived in our world.

This “lantern” set-up was not peculiar to the earth alone; all planets were the same. The famous glacial mounds which we think we see on Mars are in reality nothing but the polar openings on that particular planet.

Since the polar openings have remained as lost to us as paradise on earth, would it not be advisable to ask ourselves if perhaps at this very moment we are not living in the interior of our own planet?

**The Earth Within the Earth**

What we call the earth’s surface, the continents and the oceans, is not, as one would think, the exterior side of the globe, but, on
the contrary, the interior, concave wall of the cosmic sphere. There is no need to give credit to Cyrus Reed Teed, the advocate of this theory, for his genius because he himself explained in *The Illumination of Koresh*, in 1869, that he was not exactly the advocate of this theory, but that it had come to him as a revelation. Teed, a sort of faith healer with a practice in Utica, New York, had had a vision one night when he was lying awake and meditating.

A beautiful young woman came and revealed to him the secrets of the real cosmogony, telling him that he had been chosen for the mission of being the prophet who would bring the truth to all men. Teed seemed to have felt the anguish of the infinitely great and of the plurality of worlds to a pathological degree. He created, therefore, a universe well sealed-off, confined, and very reassuring.

The psychiatric aspect of this kind of belief comes out very clearly in the account of another conversion to the concave earth theory related by Martin Gardner: “One day in 1900, he [a hairdresser] was walking down State Street when he saw in enormous letters: ‘We live in the interior.’ A man was speaking to some idle passers-by and selling copies of *The Flaming Sword*. The hairdresser bought one. ‘I studied it in bed that night’, he said; ‘before falling asleep, I was inside the earth’.”

In Mr. Teed’s world, all that existed was contained in a sphere, the continents and oceans of which formed the inner walls. Outside this sphere there was nothing, absolutely nothing but emptiness. The entire interior of the ball was filled with an atmosphere sufficiently dense to hide the opposite side of the globe. For the same reason, we could not see the sun itself, since it was located in the middle of the world. What we took for the sun was only the reflection of the real star, which, being half-dark and half-light and turning on itself every twenty-four hours, created the succession of days and nights. The moon did not exist; it was merely a reflection of the earth. Generally speaking, all the celestial bodies were only illusions, optical phenomena.

Having established himself as the prophet of the new truth, Teed baptised himself Koresh and began his crusade. His cosmogony grew into a veritable religion. “All that is opposed to Koreshanism is Anti-Christ”, he proclaimed. Most extraordinary of all was that he succeeded in convincing people. In 1886 he settled in Chicago,
founded a review, *The Guiding Star*—and even created a Koreshien community with some of his disciples (of which three out of four were women). In 1894 the number of Koreshiens was estimated at 4,000. Koresh decided to found a city, a future centre of the world, where those who believed in a hollow earth could unite. This city was actually built in Florida, and named the “New Jerusalem”. Koresh predicted a population of eight million of the faithful. . . . Only several hundred, however, actually showed up. When he died in 1908, his followers buried him by a river. Thirteen years later a violent hurricane hit Florida and carried away Koresh’s remains, which have never been found.

The idea of a hollow earth did not die with its founder. The Koreshien journal, *The Flaming Sword*, continued to appear up until 1949, and it took no less than a fire, which destroyed the printing office, to impose lasting silence on Teed’s followers.

During the First World War a German aviator, Peter Bender, was taken prisoner in France where he came across some copies of *The Flaming Sword* and was immediately convinced of the earth’s hollowness.

The German aviator took up the works of Teed and of Marshall B. Gardner and made a synthesis of both. Bender’s universe was entirely contained in a sphere of the same dimensions as those of our earth. The sun and moon shone from the centre. A mass of bluish gas turned around the stars, hiding them most of the time. There was obviously no room in this sphere for the stars of classic astronomy; the stars were, in reality, mere specks of light. On the concave walls of the cosmic sphere, we were bombarded by radiation from the central sun. The sphere itself had no thickness. The crust on the outside extended infinitely. The luminous rays were emitted in curves, not straight lines. This peculiarity hid the real curvatures of our world from us.

Peter Bender founded a movement, the “Hohle Welt Lehre”, to spread his doctrine, and in the sick Germany of the 1930’s he drew his first followers. It was their quality rather than their quantity that was striking. Several Nazi leaders, as a matter of fact, became members of “Hohle Welt Lehre”. The hollow earth followers, who
quarrelled with the Horbigerians for Hitler’s attention, had enough influence to have organized in 1942 the famous expedition to the island of Rügen. At the most crucial moment of the war, the Reich immobilized radar systems, badly needed on the fronts, tore Professor Heinz Fisher from his work—he would eventually work on the American H-bomb—and undertook to verify Bender’s theories with the most exact scientific means. Bender, in effect, was affirming that infra-red rays moved in straight lines, contrary to the movements of light rays. In this way it was hoped that the movements of the English fleet could be followed.

Since radar was a partisan of a convex earth, Bender fell into disgrace and ended up in a concentration camp. He still has followers in Germany, even today, and one of them, Karl E. Neupert, recently published a work, Geokosmos, to support his ideas. In 1950, a theory of the same sort was proposed by an Argentinian, A. Navarro.

THE FLAT EARTH

Chicago! If any city symbolizes our materialistic and technological civilization, it is certainly Chicago. Yet, twenty-five miles outside this city is Zion, capital of the flat earth.

In the last century America witnessed an astonishing outbreak of sects, all more or less religious. Generally, the followers of a new sect founded a city—they did not lack room in America—so they could live in a community. We just saw such a phenomenon with the Koreshien faithful. Since the holders of the hollow earth theory had their city, the flat earth followers were also entitled to their own. Thus was born at the end of the last century on the edges of Lake Michigan, Zion, the centre of the “Christian Apostolic Church”, founded by Dowie.

To believe, in the twentieth century, that the earth was flat certainly represents a noble act of faith which could be fed only from the Bible itself. In fact, it was a blind faith in sacred scripture which led the Reverend Dowie to flatten our globe. His prestigious message drew him several million followers. Among them was Wilbur Glenn Voliva, who eventually became the undisputed leader of the community and champion of the flat earth theory.
Voliva saw the earth as a disc, in which the North Pole marked the centre and which was surrounded by glaciers. Thus, there was no South Pole. Sailors who thought they had reached it had simply come to the natural rail, placed there by Providence, to keep the ships from falling off the earth by skirting its edges too closely.

Voliva died in 1942, leaving a number of faithful on the edges of Lake Michigan.

But this was only one episode in the great epic of the flat earth theory. With the same design and same biblical backing, Albert Smith founded the “Universal Zetatist Society” which, among other proofs for the earth’s flatness, maintained that one did not curve railroad tracks before placing them on the supposed terrestrial globe.

Following the success of the Zetatist movement, an “International Association of the Flat Earth” was founded at Dover in 1956. Its members used aeronautics and astronautics to prove their theory. Travelling at a speed of five miles per second, Gagarin’s spaceship could only be going around an earth which spun in its orbit at a speed of 18.63 miles per second. In reality, the cosmonauts were travelling on top of the earth and not around it.
6| The Infancy of the Earth

The earth is a planet; what, however, is its history? Here again, we cannot jump to any well-established truth because the earth’s past is full of enigmas for science. Also, before going through the incredible adventures which have been attributed to our planet, as much in ancient times as in the present day, it would be a good idea to stop at this point to take stock of science’s lack of knowledge in this area.

“The abundance of enigmas is one of the charms of geology”, the geologist, P. Termier, has written. From this mass of question marks that dot the earth’s past we have chosen the two most persistent: the glacial era and the disappearance of species.

THE ENIGMA OF THE GLACIERS

The geologist Louis Agassiz who discovered the phenomena of glaciers in the middle of the nineteenth century was amazed to stumble across traces of glacier remnants in the Amazon, right in the middle of the equatorial zone. From then on, the geologists’ puzzlement has been steadily increasing because traces of glaciers have been found in all latitudes. In the Permian strata in particular (200 million years ago), glaciers seem to have covered essentially the tropical zones. Furthermore, the glaciers seem to have moved toward the poles from the equator. Yet the fossils from this era indicate that the glaciers did not cover the entire planet.

Generally speaking, we do not know the conditions necessary for the onset of a glacial era. Cold alone does not seem to have been enough to cause such masses of ice to accumulate on the continents. Such a condition would seem to presuppose heavy snow falls, leading to heavy oceanic evaporation and eventually to heat. The American astronomer, D. Menzel of the Harvard
Observatory, wrote: "If it is thought to be solar variations which provoked the glacial ages, I prefer to think that they were brought about by an increase in heat and that it was a loss of this heat which stopped their development." We can easily see the uncertainty that prevails in this domain.

In order to see things more clearly, it seems necessary to be as precise as possible about the glacial era. Two hundred million years separate the glaciers of the Permian strata from those of the Quarternary, of which the last ended about ten thousand years ago. But during the course of the Quarternary, four glacier formations followed one another in a period of one million years. It all seems to have happened as if there were well separated glacial eras during which glaciation and deglaciation alternated.

We are confronted then with a double question: what initiated the glacial eras and what caused the alternation of glacier formations and de-formations during these eras. While science cannot state with accuracy that it has accounted for all of them, traces of five glacial periods are believed to have been found. A particularly interesting phenomenon is that these seem to have been separated by periods of 250 million years.

If it could be proven, this periodicity would perhaps be the first key to the enigma because it corresponds to the galactic rotation. One could believe that at one point in its course around the galactic nucleus the solar system passes through a cloud of cosmic dust which partially intercepts solar radiation.

Ernst Opik, the astrophysicist, explains this periodicity by phenomena peculiar to the sun, which every 250 million years would cause it to lower its rate of radiation.

A Yugoslavian, Milankovitch, has pointed out a striking correlation between the evolution of the terrestrial position with regard to the sun and the temperature of the globe in the course of the last 600,000 years. If this is true, however, the retreat and forward movement of the ice should have happened regularly throughout the geological ages.

We spoke earlier of paroxysms of volcanic activity pouring out tons of dust into the atmosphere. It is a fact that the explosion of Krakatau (1883) alone "contaminated" the atmosphere to the point of lowering the mean temperature of the planet.
68/The Earth is Alive

Let us bear in mind, at any rate, that the setting in motion of a glacier formation does not presuppose a drastic drop in temperature. Several degrees should suffice.

Scholars are just as much divided on the problem of climatic fluctuations during these glacial periods. It seems fairly clear that the earth has a thermoregulative system like that of higher animals. From this point of view, Dr. Jaworsky’s geon offers an excellent comparison. Our planet regulates its temperature as would a living being.

Many think they have found the regulating agent in carbon dioxide. Our atmosphere contains 0.03 per cent CO₂. This gas possesses the remarkable property of creating a hothouse effect. It keeps the sun’s warmth at the earth’s surface, preventing it from rising into the cosmos. Thus an increase in the level of CO₂ in the atmosphere would have the effect of raising the earth’s temperature. If, for example, the level doubled, the temperature would be 3.6 degrees Centigrade higher; if on the other hand, it was cut in half, the temperature would drop by 3.8 degrees Centigrade. This level depends, among other things, on the exchange between the hydrosphere and the biosphere, which can influence the terrestrial temperature. But certain oceanographers, such as Maurice Ewing and William L. Donn, think that this thermoregulative role is played by the oceans. The one thing we are sure of is that there is an earth-thermostat, but we do not know where it is. It has also been proposed that there is a periodic change in the earth’s axis of rotation, but besides sounding physically impossible, Professors I. M. van der Vlerk and P. H. Kuene have pointed out that “no matter where you located the poles, the equator would always run along one or more glacier formations”.

To conclude, the scholars are all in agreement on one point: that the phenomenon remains unexplainable. “Of all the theories which have been proposed to explain the ice ages, not one deals with the facts in such a way as to inspire confidence”, wrote W. B. Wright in The Quaternary Ice Age (1937). Similar confessions of ignorance are found in all works dealing with this question.
THE VIRGIN FOREST AT THE POLES

Unfortunately for these scholars, the ice ages do not constitute the only enigmas that the earth seems to delight in presenting. What are they supposed to think when they come across coral reefs in Spitzberg? Polyps can only form in warm sea waters. The Mediterranean, for example, is too cold for coral. One can well wonder at what animals who would shiver on the Côte d'Azur were doing in the Artic Ocean.

The only likely answer, obviously, is that lands near the Arctic circle at one time had a warmer climate. If anyone has any doubts about this, remnants of fig trees, magnolia, and palm trees which have been found in these regions should be sufficient to dispel them.

Let us pass now to the other end of the planet, to the cold lower regions: the Antarctic. This continent once had a tropical climate as well. Irrefutable evidence for this lies in its soil, in the form of vast deposits of coal. Coal, as we know, comes from the decomposition of vegetable matter. Since layers of coal have been found in the Antarctic, we can know for sure that its land was covered at one time with luxurious vegetation, most likely tropical. The problem of polar vegetation is very special. In effect, a general heating of the planet would not have kept these regions from being immersed in the dark six months a year. A superior vegetation could not have developed in these conditions, no matter what the climate was like.

The equator covered with ice and virgin forests at the poles present us with our first enigmas. It sounds like something out of a detective novel.

THE GENOCIDES OF THE PAST

Palaeontology has uncovered the remains of some 2,500 species of animals. Only one-third are still in existence today. On the average, each of these species lived only 75 million years, which does not, however, keep certain existing species from going back to the Primary Period. The record for longevity seems to belong
to a small brachiopod, the Lingula, whose ancestors were already alive 400 million years ago.

Throughout the geological ages, terrestrial fauna was periodically exterminated. Entire species and family groups disappeared while others took their places.

In the Permian strata, nearly half the existing animals, terrestrial as well as aquatic, disappeared. We have lost all traces of 84 per cent of the reptiles. Another example of genocide occurred at the end of the Triassic Period: out of twenty-five known ammonites, twenty-four disappeared. The ammonites (cephalopods, called thus because they reminded the paleontologists of the god Ammon) had several periods of regression and development. After a quasi-disappearance in the Triassic Period, this species flourished in the Jurassic and the Cretaceous Periods and disappeared abruptly at the beginning of the Tertiary Period. At the end of the Cretaceous Period, a new drama carried off a fourth of all known animals.

Finally, not too far from our own age, after the last Quaternary glaciers, a wave of extermination swept through the animal world. Certain species disappeared, leaving no traces anywhere on the earth, while some managed to survive in some regions.

The result of this last drama was as horrifying as anything that had preceded it. In India alone, thirty species of elephants had come into being; only one remained. In all the animal families, this was a common occurrence.

By the Quaternary Period, North America was inhabited by mastodons, hairy rhinoceroses, horses, giant bisons, dwarf elephants, elks, and saber-toothed tigers (samilodons). By the beginning of our civilization, these last representatives of these species on American soil were all dead. Take the case of the horse, for example. America was the cradle for this species, and it passed from America into Eurasia. Until the end of the Quaternary Period, it roamed around the American plains in big herds. By the end of the Quaternary Period, the horse had inexplicably disappeared. It was not to come back until the sixteenth century with the fleets of the Conquistadors.
CUVIER'S CATASTROPHES

The formation of the terrestrial crust, the glacial periods, the extinction of species—the earth had hidden all these things from us! Science observes, records, clarifies, and studies, but it still cannot proceed with certainty from the effects to the causes. All it can do is to propose tentative hypotheses.

Among these two main currents of thought can be distinguished catastrophe and uniformism.

It all started at the beginning of the nineteenth century when Cuvier announced to the Parisians that elephants, mammoths, and many other extinct animals were buried underneath their city. When major construction was going on there were discovered the remains of crocodiles, turtles, mammoths, sharks, reindeers, rhinoceroses, bisons, beavers, etc. It was obvious that the Parisian climate had known drastic fluctuations as had other regions of the globe. Strangest of all is that the remains of animals who lived in very different climates are often found mixed together. A science founded on the Bible had not foreseen this.

The founder of palaeontology was very impressed by the arrangement of the fossils in superimposed layers. He deduced that the fauna had changed at different points. This was supported by the fact that marine fossils alternated with the remains of land animals. Besides this, he noticed that certain species had disappeared for good while others had suddenly reappeared.

For Cuvier, there was no doubt about the conclusion: "Life on this earth has often been plagued by cataclysmic events." He thought that most of these catastrophes which accompanied maritime fluctuations had been sudden. "This is easiest of all to prove for the last of these catastrophes", he explained.

What proofs did Cuvier have in mind? Essentially, the famous Siberian mammoths.¹

¹ In the eighteenth century, the German naturalist P. S. Pallas discovered not the skeleton, but the intact body of a mammoth. Numerous similar finds have been made since then. (In 1930 the Academy of Science in Moscow dined on succulent mammoth steaks.)

Naturalists discovered buttercups in the mouth of one of these animals and reeds in its stomach. From this they concluded that the animal died between July 15 and August 1. This proved, too, that the climate was warm.
All the scholars—Cuvier at their head—who dwelt on this problem, came to the conclusion that a sudden and very steep drop in the temperature had taken place, a climatic catastrophe. No natural force presently observable is capable of being able to lower definitively and in several minutes the temperature of an entire continent in such proportions.

Cuvier concluded: "It is futile to look for what produced the revolutions and catastrophes whose traces are still present on our earth in the forces that we know today."

LYELL'S CALM WORLD

When Cuvier introduced his "catastrophe" postulate, he believed, along with all his contemporaries, that the earth was only several million years old, that its face had been patterned by the flood, and that only a cataclysm could reshape it again. What had to be found out was if there had been one or several tumultuous events. They thought, in effect, that the earth was an unmoving, inert body, which in normal times did not change. Only the intervention of violent forces could change its face.

It was the role of a young man, fresh out of Oxford, to do away with this belief. Lyell has as much a right to being called the father of geology as Cuvier does to being considered the father of palaeontology. He discovered, in effect, the source of geological forces: duration.

Lyell saw that the earth was in a perpetual state of change before man’s very eyes, but the rhythm of this evolution was so slow that the ordinary observer easily missed it. The young geologist came to the conclusion that if these same forces that are acting right now have been doing so for millions of years, they could very easily have created mountains, wiped out continents, dried up oceans, in short, changed the face of the earth. All that had to be done was to

But the state of conservation in which the animals were found proved that they were brutally and quickly frozen. They died from the cold, suddenly, in the middle of summer.

Similarly, Baron Toll discovered, in the New Siberian Islands above the Arctic Circle, fruit trees whose leaves and fruit had been perfectly preserved by sudden freezing.
attribute several million years to the earth to explain its past by means of its present. Lyell had discovered the key to geology: duration transforms the infinitely small into the infinitely big, inches into miles.

The appearance and disappearance of the various species still remained to be explained, however. Darwin provided the answer to this. Influenced by Lyell, he explained the changes in land fauna by the vital struggle of evolution.

UNIFORMISM OR CATASTROPHISM

Present-day science has chosen uniformism and the actualist postulate by an immense majority. "If we limit ourselves to inorganic phenomena alone, we can be actualist with a maximum of certainty", Professors H. and G. Termier have written. This is typical of the modern scientific position.

Still, uniformism is far from being able to give a complete account of all the geological and palaeontological phenomena of which we have found traces.

To illustrate this point, let us return to our genocides and examine what hypotheses uniformism has come up with to explain them. It has proposed changes in climatic conditions; but why did the animals succumb at the end of the last ice age in the Quaternary after having withstood the three before it? Man's action has been cited as a possible cause, namely his setting forests on fire to hunt out game; but is this not saying too much for the efficacy of the neolithic Nimrods? Were the species wiped out by epidemics? Germs usually only attack one species at a time. An epidemic wiping out a quarter of all the land fauna is very unlikely.

The most widely held hypothesis, finally, is that of maritime fluctuations.

The melting of the Quaternary glaciers made the levels of the oceans rise, submerging part of the continents. The decrease in the amount of uncovered land would have made the conditions of the struggle to live even harder.

But this thesis, tempting as it is, does not explain why in numerous places, piles of bones, broken and showing signs of extreme violence, have been found because for the scholars the
rising of the ocean was gradual, without any violent currents in the tides. Thus, very few animals should have perished. This thesis also fails to explain the tragic end of the Siberian mammoths.

Scholars admit that they do not see how the actualist position takes these genocides into account. Other facts seem difficult to reconcile with uniformism; stretches of lava bigger than France (in India and Brazil), oddly situated blocks that seem to have scaled heights, etc. This does not mean that the actualist stance is necessarily wrong. It is the very base of geology and no one seriously contests it. The one problem is that of knowing whether it should totally exclude all catastrophes. In his work, *The Lost America*, Professor F. C. Hilben described pits filled with bones in Alaska: “The marks of violence are as flagrant as in the German concentration camps. We find proofs of atmospheric disturbances of an unheard of violence. The animals were dismembered and thrown about the countryside like pieces of straw, even though some of them easily weighed several tons. The Quaternary ended with the extermination of life... not an ordinary end... but a total and catastrophic annihilation.”

The pits of Alaska are not unique. All over the world there have been found charnel houses of this nature, piled high with the broken remains of thousands of animals.

In order to be able to deny catastrophism completely, we would have to be sure that space and time were homogeneous. This is obviously out of the question; we can see it. The earth can never be found in two places at once in the cosmos. And cosmic space is not empty, and it changes from one place to the next, from one minute to the next. The explosions of supernovae, variations in cosmic rays, the vectors of forces of the galaxy’s magnetic field, the clouds of cosmic dust, all make it a predominantly heterogeneous milieu.

The proposition cannot be absolutely excluded that terrestrial events in this fluctuating world did not have serious repercussions all over our planet.
The Lesson of the Flood

Like any loyal subject of Queen Victoria, George Smith held as established the authenticity of the biblical flood. This young man, twenty-one years old in 1863, had never studied anything but engraving. He was a very skilful artist, charged with designing the bills for the Bank of England.

Besides his work, the young artist was passionately interested in the study of Mesopotamian civilizations which had just recently been uncovered. The British Museum was his headquarters, and the works of the archaeologists were his bedside reading.

He spent so much time in the museum’s galleries, between a piece of glued pottery and a fragment of a bas-relief, that he drew the attention of Mr. Birch, the curator of the Oriental antiquities, precisely because the latter was looking for an assistant.

H. Rassam, the archaeologist who had executed one of the excavations on the site of Nineveh, had come across the library of Assurbanipal. The “books” were tablets of baked clay covered with cuneiform inscriptions. The collapse of the palace had done much harm to these fragile documents whose full importance was not immediately appreciated. At first, in fact, the archaeologists took them for “decorated pottery”.

The tablets were so roughly treated that the number of fragments increased considerably between the Middle East and London, Birch was at his wits’ end when he finally received them. In despair, he turned them over to the amateur archaeologist.

The Question of the Flood

Smith did not merely reassemble the pieces, but also tried to interpret the tablets which he was gradually reconstructing.

He pursued his task for nine years, until he came upon Tablet
XI of Gilgamesh. By 1872 when he had finally translated the text, all that remained for him was to present to the Royal Society of Biblical Archaeology a report on the “Chaldean account of the deluge”. Smith had just uncovered a pagan version of the flood, much like that contained in the Bible.

The commotion that followed the discovery of the Dead Sea Scrolls can only give a weak idea of the emotional upheaval caused by this event. The pagan account was obviously a good thousand years earlier than the Bible, for one thing. Furthermore, it was not just a question of the same event, but of the same narrative.

The public became totally wrapped up in the affair, and the Daily Telegraph gave Smith the funds necessary to allow him to pursue his studies on location. One week after his arrival on the banks of the Tigris, Smith discovered a tablet which completed the one in the British Museum. When George Smith read the account of his discovery in the Daily Telegraph, however, he was surprised to learn that “the excavation campaign was over”. Since the newspaper had received the publicity it wanted, it no longer intended to subsidize the investigations.

From that point on, many other cuneiform tablets dealing with the flood have been unearthed, but the most complete account remains George Smith’s XI Tablet of Gilgamesh.

A Sumerian version of the flood has also been discovered. Nothing proves, however, that the Sumerians invented the legend, whose origins have been lost in the depths of antiquity.

In the famous passage from Genesis, specialists have recognized the existence of two separate accounts which contain several divergences of details. There are the Jahweh, or J, version (in which God is called Jahweh), and the sacerdotal, or P, version (in which God is called Elohim). The J version, antedating the P version by two centuries, still seems to bear traces of a primitive paganism.

The Mesopotamian flood was one of the twelve episodes in the epic of the Babylonian hero, Gilgamesh. Each episode had its place under a sign of the zodiac, the flood’s corresponding to Aquarius.
The story is told by the Babylonian Noah, Uta Napishtim, to his descendant Gilgamesh. The gods, having decided to engulf the city of Shuruppak, one of them, Ea, warned Uta Napishtim and advised him to build an ark with which to shelter his family and some animals. The hero followed the instructions, survived the cataclysm, and the god Enlil bestowed immortality on him.

There are numerous instances where details resemble one another in the Biblical and Babylonian accounts: the boat covered with tar, the embarkation of the animals, the releasing of the dove, the stranding of the ark on the mountain, the sacrifice, the blessing of the survivors, etc.

The Sumerian fragments and the later narrative of the Chaldean priest, Berose, do not differ in any essential way from the Biblical and Babylonian versions.

Greek mythology had three floods, the respective heroes being Deucalion, Ogygas, and Dardanus. The legend of Deucalion is by far the most famous, however. Zeus having decided to wipe out mankind in the Bronze Age, Prometheus warned his son Deucalion and advised him to build a covered boat in which the hero embarked with his wife, Pyrrha. It rained for nine days and nine nights, and on the tenth day the ark came to rest on Mount Parnassus.

This myth was very long-lived in Greece. In Zeus’s temple at Athens there was a crack in a rock which was supposed to have served as a drain for the flood waters. During annual ceremonies, they threw water, honey, and flour upon it to commemorate the victims of the cataclysm.

There is no need to compare the Biblical and Mesopotamian texts at length; from all evidence it is a question of two versions of one narrative. This finding is not at all surprising since the Bible has Abraham coming from Ur in Chaldea. It even appears that the name of the hero remained the same, under different forms. The Sumerian hero was called Ziusudra, which can be translated by “prolonged day of life”. In Semitic language, Uta Napishtim means “day of life”. It is a question then of an abbreviation of a Sumerian name. Berose called his hero Xisoustrhos, a transliteration into Greek from the Sumerian Ziusudra. Noah has been
traced to the Egyptian Nôha, “to have a long duration, to be far off”.

Deucalion’s flood seems to have been inspired by the Sumero-Chaldean tradition, but no decisive proofs are possible for this or for the Persian-Hindu accounts. All of these myths confront us with disturbing similarities, and that is as much as we can say for any of them.

The connection is obviously much more problematic for more ancient diluvial legends that are found to some extent in all mythologies. Certain peoples lived in fear of a return of the flood. The Mandan Sioux celebrate the feast of O-Kie-Pa every year during which they relive the flood.

Offerings are made to rivers to prevent the return of the catastrophes. A tribe of Asiatic pygmies, the Semangs of Malacca, wound and mutilate themselves when thunder rumbles, spilling out their blood on the ground to prevent the flood from returning.

These different accounts did not stem from imaginary forces, but from the simple unchaining of the elements. From this, would it not be possible to reconstruct the actual catastrophe by going through the different accounts and comparing the results with local conditions?

This experiment was tried by the great Austrian geologist, Suess, in the beginning of his colossal work, The Face of the Earth. For him, the cataclysm had to be localized since Egypt had no tales about it. He thinks that the diluvian tradition goes back to an extremely violent earthquake followed by a tidal wave and torrential rains which fell on Asia Minor. The chain of these phenomena is something that recurs frequently. We know, for example, that the earthquake that ravaged Lisbon in 1775 was followed by a violent tidal wave.

It should be noted that in Genesis only the J version spoke of rain while the P version spoke only of waters that flooded the earth. The Gilgamesh account was not precise about the origins of the waters.

On the other hand, in this perspective, the divine announcement of the flood can be easily understood. We know that there are often a certain number of signs before a cataclysm. There is nothing
wrong with thinking that certain inhabitants knew how to interpret these signs correctly and eventually took flight, perhaps by embarking and leaving the country by sea.

Would such a catastrophe have left traces on Mesopotamian soil? What more spectacular evidence could one want than the ark itself. Periodically men climb Mount Ararat (16,915 feet) to try to find it. In 1916, a Russian aviator claimed that he saw its skeleton while flying around the mountain. His testimony was lost in the turmoil of 1917. In 1949, an American missionary, “ordered by God”, headed an expedition to Mount Ararat. The divine command must have been incorrectly interpreted, however, because the Reverend Smith found no trace of any boat on the mountain. In 1952, it was the Frenchman J. de Riquier’s turn to head a search for the ark. Without a doubt, other adventurers will go on looking for it.

THE MARK OF THE WATERS

In 1926 systematic excavations were undertaken on the site of Ur by Sir Leonard Woolley. The archaeologists uncovered terrain filled with pottery debris and other vestiges of human activity. Then suddenly they came upon a virgin layer of dirt containing no trace of human habitation whatsoever.

Different observations incited Woolley to pursue the work. Water carries alluvium with it. This layer of barren earth was formed of clay of alluvial origin. After having dug down 8.2 feet into the virgin layer, the researchers came across a layer of a different nature which contained once again signs of human life which were thought to have gone back to the fourth millennium. The date, the formation of the strata, all led to one conclusion: the flood. So Woolley made known right away that he had just found traces of the biblical flood.

At the same time, Stephen Langdon, excavating at Kish on the site of Babylon, made a similar discovery. Everything agreed: they had found the flood. Marston wrote: “The two scholars discovered simultaneously sedimentary deposits left by the great flood.”

Soundings were even made on the sites of Uruk, the city of
Gilgamesh; of Shuruppak, the city of the flood; of Lagash; of Nineveh. They found everywhere the famous layer of lime separating the debris-filled strata. Nowhere, however, did it reach as far as the 8.2 feet at Ur.

Would this be taken as proof for the Mesopotamian flood? The specialists undertook to date these barren layers with precision. For the deluge of Ur, it was easy. Under the clay, debris of fine ceramic characteristic of the Ubeid period, which goes back to the fourth millennium, was found. A more thorough examination of the place produced some traces of these ceramics just above the alluvions.

Research of the same order at other excavations showed, on the other hand, that the sedimentary deposits went further back in time than at Ur by several centuries.

Thus, they had found not one, but several floods. At Ur and Nineveh, the cataclysm took place in the fourth millennium. At Babylon, Shuruppak, and Uruk it happened in the third millennium. Scrolls bearing the name of Gilgamesh—who is definitely supposed to have been a post-diluvial hero—were found at Kish under the alluvial layer.

Suess had envisaged the possibility of violent earthquakes. Such a catastrophe would have left traces. Mr. Schaeffer found seismic marks of an exceptional degree in the periphery of the Mediterranean basin. His work in comparative stratigraphy proved that the Middle East was shaken by shocks of unequalled violence at six different times in the course of the three millennia which preceded our era. These shocks marked the end of the ancient and middle Egyptian empires as well as the Hittite empire.

Schaeffer concluded: “Our search has shown that these successive crises by which the principal periods of the third and second millennia opened and closed were not provoked by the action of man.”

In terms of this study, what can we make of the historic problem of the flood? Repeated catastrophes shook the Mesopotamian world; we are certain of that. Why should we believe that one rather than another started the legend? It is not impossible, but on the other hand, no certain proofs can be offered.
The diffusion of the legend remains to be explained. It is hardly likely that all of the accounts go back to one particular catastrophe. The myths, then, would have sprung up independently, in some cases as the result of localized floods, in others as pure fiction and, most likely, with symbolic and mythological contexts.

We could well believe, as did the French archaeologist J. de Morgan, that the flood originated in the distant past out of a general disaster brought about by the melting of the great ice packs of the Quaternary. For J. de Morgan, the flood probably occurred in the middle Pleistocene Epoch, at the end of the third Quaternary ice age. If this is so, it must have been a brutal and repeated cataclysm, and must have occurred in different ways and at different times according to the regions.

For other archaeologists, such as H. Peake, the flood goes back only as far as the last ice age, roughly ten thousand years. In this case, it would correspond to the extraordinary extermination of animals, traces of which were found in this era.

The formation of the myth can be more easily conceived in such a perspective—whether it is Morgan’s or Peake’s. What has been brought from the past together with the abundance of the evidence would seem to indicate that men started off from there on the way to a second humanity. The case for a purely local phenomenon does not seem as strong.

Geographical and mythological conditions were sure to provide fertile ground for the formation of a myth or else, on the other hand, for completely forgetting the phenomenon. Floods had a profound symbolic significance for primitive people. Water embodied the undifferentiated principal of life. Earth represented a first materialization of this principle. Because of this, it was inserted into time and found itself condemned to degeneracy. Water, on the other hand, kept all the life principle, without undergoing any degradation: it represented eternal life. It possessed a regenerative power that is found in the general symbolism of baptism. From this point of view, the flood took on the meaning of a cosmic baptism, regenerating a worn-out earth.

There existed, then, in the primitive mentality, a symbolic context which was fertile ground for the development of the diluvian myth. Let us note on this subject that Africa seems to be
both the region of the globe which suffered the least from the Quaternary ice packs and the one that remembers the least about the flood.

The one certain fact is that the flood remains a mystery as to its historic origins. Many hypotheses exist, but there is no certainty. We wanted to demonstrate with what caution legends must be used as historical evidence. This seemed necessary before examining the history of past catastrophes, which most of the time are precariously based on legends.

**THE GREAT YEAR**

For most traditions, the flood is a part of the greater myth, that of the Great Year, of the periodical destruction of the world. It seems that this belief originated in Chaldea, the cradle of astrology.

The Great Year is the period between two similar, cosmic catastrophes. There was no doubt in the minds of the Ancients that all life was exterminated at regular intervals. For the Chaldeans, these annihilations were linked to the movements of the celestial bodies. When the planets were in conjunction with Cancer, an enormous fire broke out, a conflagration which covered the entire planet. It took place in the summer of the Great Year. When, on the other hand, the conjunction was with Capricorn, a universal flood engulfed the world; this occurred in the winter of the Great Year. The entire cosmic cycle ran 432,000 years.

If one believes Plato, the Egyptians also adopted this myth, which was to become one of the leitmotifs of Greek thought. For almost all the Hellenic philosophers, cyclic catastrophism had the value of a dogma and a postulate; but everyone had his own personal version. All Asiatic traditions had such cycles. According to the Hindu Bhagavata Purana, humanity is in the fifth age—the humanities of the preceding ages were all destroyed by calamities. The sacred writings of India named as destructive agents water, fire, and wind. Buddhist philosophy, for its part, believed that the earth was seized with convulsions at the end of the Great Year. Persian Mazdaism, likewise, predicted such periodic cataclysms, and Zoroaster placed them at the end of each millennium.
According to rabbinical commentaries, ten earths were successively destroyed. One of these exterminations was marked by a flood.

The pre-Columbian peoples created the most horrifying, most sinister, and calamitous universe one could possibly imagine. The Aztecs, Mayas, and Incas lived with the memory of and in perpetual expectation of the worst catastrophes. Every dawn was met with happy surprise, and the day of the Apocalypse would have caused no consternation whatsoever. Blood from sacrifices kept the solar system in existence, but it was understood that from one day to the next cosmic mechanisms could easily stop, and general extermination would result. Then another sun would rise on another world. The gods’ blood would start it going and men’s blood would keep it going until the day when all would be destroyed once more.

In Germany, in Iceland, in Borneo, Hawaii—everywhere, in fact—men have told tales of catastrophes which destroyed all vestiges of life.

Was budding humanity shaken forever by the holocausts it witnessed? This is perhaps the moment to return to what we said about the mother earth myth. For the man in the street who has not experienced the anxious vigil for the fruition of the earth, or the fear of its anger manifested in earthquakes, volcanoes, tidal waves and so on, all this seems remote and alien. Yet these myths and legends symbolize terrestrial reality such as it was for the first men.

Man discovered the nourishing power of the earth in its most unstable zones, under the harsh conditions of the ice ages. Through his myths and legends, man has left us a record of his awe of the earth, his fear of its cataclysms, and his terror that its fecundity might end.
In 1930, within the venerable enclosures of the Sorbonne, protesters sabotaged a lecture by throwing tear gas bombs. Surprisingly enough, the topic under discussion was not something like the future of Bolshevism or the ideas of Charles Maurras, but Atlantis.

Atlantis, that mirage of mirages, represents the permission to dream guaranteed by a great philosopher, the opium of inquisitive souls, whether insane or serious. It is either a crucial problem in human history or the most baffling mystery of all time.

At the origin of this search is one man alone: Plato. Here is the passage on Atlantis from *Timaeus*: “This island was bigger than Libya and Asia put together, and travellers at that time could pass from this island to the other islands, and from these islands they could get to the continent, on the opposite side of this sea, which truly deserved its name. On one side, inside the strait of which we are speaking, it seems that there was only one harbour with a very narrow entrance, and on the other side, there was a big sea. The land that surrounded it could be called a continent in the proper sense of the word. On this island of Atlantis kings had formed a great and marvellous empire. This empire controlled the entire island as well as other islands and parts of the continent. Besides this, on our coast, they held Libya as far as Egypt, and Europe as far as Tyrrenhia. When this power had amassed all its forces, it undertook to enslave your and our territories, as well as others on this side of the strait . . .”

Everybody who has studied Atlantis has consulted this unique source.

The philosopher speaks of Atlantis in two of his dialogues, *Timaeus* and *Crito*. There is an enormous difference between the
two texts. In the first, he seems to be writing simply and naturally about a mere historical event. In the second, however, he sets out to describe Atlantis’s civilization. Without going into an exegesis of the texts, it should be noted that most specialists look upon the historical character of *Crito* much more skeptically than they do that of *Timaeus*. For one thing, there is obviously a great deal of platonic invention in the former.

Plato set the date for the cataclysm that wiped out Atlantis as being nine thousand years earlier. It is understandable that mankind might hold in its memory something that happened so long ago, but it is very doubtful that everything would be remembered.

We will remain extremely cautious, then, in our appraisals of *Crito*. We still have *Timaeus*, however. In this dialogue Crito recounts a narrative that an Egyptian priest is supposed to have related to his ancestor, Solon. The priest from Saïs explained that at one time a tremendous island lay in the middle of the Atlantic Ocean, opposite Gibraltar. Its inhabitants, the Atlantians, tried to dominate the people on the continent, but were conquered by the ancestors of the Greeks. Nine thousand years before Solon’s time, Atlantis was suddenly destroyed by a cataclysm and sank down into the waves forever.

That is the only documentation on Atlantis that we possess, except for occasional scraps of information here and there. The ancients had never heard anything about this legend, and most of them, especially Aristotle, thought that Plato had simply made the whole thing up.

Over a period of two thousand years men lost all interest in Atlantis. Aristotle’s incredulity alone was enough to turn it into a fable.

The sixth-century geographer who shut the earth up in the tabernacles of Moses, the monk Kosmos, made Atlantis the home of antediluvian man, a sort of earthly Paradise. This hypothesis was about the only one proposed during these two millennia.

After the discovery of America, there was a change of attitude, however. Contrary to what one might think, Columbus’s contemporaries did not immediately associate the New World with Atlantis. Another fifty years elapsed before the Spaniard, Gomora,
advanced this hypothesis. Not long afterward, Serranus, a translator of Plato, transported Atlantis to the European side of the ocean and placed Palestine in it. In 1665, a Jesuit, Father Athanase Kircher, maintained that everything had happened exactly the way Plato said it had, and he published a map of the Atlantic with the island kingdom of Atlantis in the middle. Ten years later, however, the Swede Rudbeck claimed Atlantis for his own country, stating that its capital had been the Swedish city of Uppsala. Although this hypothesis no doubt presented its author, who incidentally happened to live in that city, with all sorts of opportunities, Atlantis did not remain Scandinavian territory for long. A decade after the Rudbeck version of Atlantis, the German Bock pushed it down past the equator and placed it in South Africa. After being shuffled around for a while along the Ceylonese coast, it returned to Europe with Delisle de Sales, who installed it in the Caucasus in 1779. At the same time, Bailly, the future mayor of Paris, dispatched it north and held that the Atlantans had populated Spitsbergen.

In the nineteenth century, the hypotheses about Atlantis started to come so thick and fast that it was impossible to keep track of all its movements. It was simultaneously located in Persia, Crete, Attica, Nigeria, the Sahara, in North Africa, Spain—on the site of ancient Tartessos at the mouth of the Guadalquivir—and in many other places as well.

Indeed, since Plato not one new fact has been uncovered that can be added to the Atlantis file—that is, none which have not been tinged with suppositions. The result is that with a little imagination it is quite easy to come up with a new theory; but on the other hand, it is just as impossible to wrap up in any kind of coherent way all the possible theories about Atlantis. We are nevertheless going to try to impose some kind of order on all these hypotheses.

WAS IT MEMORY OR IMAGINATION?

Anyone reading Timaeus will probably begin by wondering whether he is dealing with fiction or reality. Most scholars lean toward the former. In their work From Atlantis to El Dorado, Willy
Ley and Sprague de Camp support this thesis with considerable elaboration. According to them, Plato thought up this story only to embarrass the Egyptians. By having one of them tell the story, he took away any reason for their disputing it. And by means of this legend, he proved that Greek civilization was as old as theirs and that at that time the Egyptians were quite happy to have the Greeks call a halt to the Atlantis invaders.

This seems a coherent and appealing thesis. We still have to determine whether Plato was wrapped up in the question of national susceptibilities to the extent of mixing fables in with his philosophy.

If we choose to make of Atlantis a simple philosophical fable, it must be confessed that its meaning is anything but clear. In *Crito* we certainly see the dramatization of a certain number of platonic themes, but, on the other hand, *Timaeus* seems stripped of such embellishments, and its form is that of a historical narrative, rather than a philosophical theory.

However, the possibility that Plato did not invent his story does not imply that it is authentic. After all, he was only talking about a tradition, so it is possible that he was lying without his realizing it.

For the sake of argument, let us suppose that there is “some element of truth” in the account; we are still wandering around in the middle of a labyrinth. To clarify the problem somewhat, we shall divide the issue into two parts:

1. An island, as vast as a continent, suddenly sank into the ocean.
2. An advanced civilization existed in the second millennium B.C.

**Can a Continent Disappear?**

Can a continent as vast as the island described by Plato suddenly disappear into the ocean? Geophysicists deem it impossible. For the scholars, the vertical movements of the earth’s crust can be considerable, but they always maintain a very slow rhythm. As Professor Termier puts it: “In geology, a million years are necessary for anything to happen.” Only twenty-four hours were
necessary to engulf Atlantis. This does seem a somewhat swift operation.

We could say, of course, that Atlantis was much smaller than Plato’s island and that its disappearance was not as rapid as was claimed. Even so, can an island of only average dimensions be swallowed up so quickly? To find out, let us try to recreate what was happening on the earth 11,500 years ago. At the beginning of the tenth millennium B.C., the last ice age, that of Würm, covered Europe and North America. The formation of these ice packs considerably lowered the level of the oceans. The difference was one of 425 feet in relation to the present level. Then, abruptly toward the ninety-sixth century before our era, the glaciers melted and the ocean level went back up. In a very short time, the waters were three hundred feet above their preceding level.

This fluctuation was indeed rapid, but it nevertheless took longer than one day. If it happened as it should have, it was spread out over several centuries. Furthermore, a rise of three hundred feet in the water level, while having considerable consequences, would still not be sufficient to engulf an entire continent. Nowhere in the Atlantic, except for the continental shelf, are there such shallow depths. Thus, while the fluctuation submerged a large part of the Atlantic coastline and the islands, this phenomenon does not correspond to Plato’s description. If we study the account of the Egyptian high priest, we learn that “there were terrible earthquakes and cataclysms”. Here is a new piece of information.

The most recent theories hold that the Atlantic Ocean was formed by the simultaneous separation of the New and Old Worlds. The line of demarcation was materialized by the chain of volcanic mountains that follow precisely the middle of the ocean. All over the centre of the bottom of the Atlantic Ocean, particularly near Gibraltar and the Azores, the ocean floor is extremely volcanic and unstable. Thus in 1957, in the area of the island of Fayal, a volcanic island suddenly emerged from the ocean, erupted for a whole month, then sank back down into the ocean.

To find out what the amplitude of these volcanic and seismic crises was in this region, we can refer to an observation made by Professor Pierre Termier. At the end of the last century, sailors who were placing a telegraphic cable on the ocean floor in the
vicinity of the Azores, brought back to the surface some mineral fragments. The grappling-irons had found them more than 9,800 feet down. This find indicated that the ocean floors were not covered with sediment and were therefore of recent formation. In analysing the fragments, it was found that they were tachylites, which is a glassy, basaltic kind of lava. Lava, however, does not vitrify under water. This meant that the lava that lay 9,800 feet under the surface had recently solidified in open air.

Here, then, is a particularly instructive episode, which leads us to think that a period of especially intense volcanic and seismic activity might have produced a general cave-in in the median zone of the Atlantic. From this perspective, recently developed by the submarine archaeology specialist Mr. Foex, the Canary Islands, the Cape Verde archipelago, and the Azores constitute an “Atlantic residue”. And Plato could easily have inordinately extended Atlantis, which was probably supposed to have been an Atlantic Polynesia.

Such is the cautious but interesting position adopted by most scholars.

**ALL SONS OF ATLANTIS**

Much more interesting are the inhabitants of Atlantis, for the geological aspect alone is not so spectacular. When we think of an unknown civilization, one which is at the same time the most ancient and perhaps even the most advanced, we have a true elixir for the imagination.

One of the first to be fascinated by the problem of its inhabitants was a particularly colourful American, Ignatius Donnelly, who announced in *Atlantis, Antediluvian World* (1882) that all civilizations derived from Atlantis, the crux of its knowledge having been secretly propagated by an elite, elected few. The myth of Atlantis had discovered a method of spreading its gospel.

Just a few years earlier, a French abbot, Brasseur de Bourbourg, had been working on a highly fantastic translation of Mayan manuscripts and maintained that he had found a description of an alleged country of Mu which had been destroyed by a cataclysmic volcano. The similarity between Mu and Atlantis was easily
apparent. Furthermore, since the pre-Columbian and Egyptian civilizations resembled one another, there could be no doubt that all ancient civilizations were but colonies of Atlantis.

Gradually Donnelly claimed that the Atlantans invented everything: gunpowder, of course, as well as the compass, astronomy, tiles, and circumcision.

The Atlantis mania bordered on the insane with the theories of the pseudo-occultists of the nineteenth century, especially that of the famous high priestess of theosophy, Helena P. Blavatsky. She claimed that the race of the Atlantans was the fourth of seven succeeding races which have appeared on earth, and that this race was offered as a homeland an immense continent encompassing America. The history of the Atlantis civilization was supposed to have lasted from the year one million to the year twenty-four thousand prior to our era. This race was subdivided into three sub-races, of which the most intelligent, the Toltecs, was familiar with such diverse things as telepathy, battle ships, and transparent clothing for its courtesans. The Atlantans degenerated, however, and on several occasions divine punishment fell on their country, gradually reducing it to one covered with a mantle of sorrow. Plato’s account of the catastrophe represented the final phase of this process. Before the end, however, the “Great Order of the Initiated of Atlantis” had emigrated to Egypt, carrying with it its marvellous secrets.

These daring hypotheses should not make us lose track of the original problem of whether a civilization could have existed ten thousand years B.C.

Here we have the meeting point of archaeology and prehistory. Civilization, properly so called, never stops receding in time. Within the past few years, the archaeologist J. Mellaart unearthed at Chatal Huyuk (Anatolia) the remains of a civilization estimated to have developed seven thousand years before our era. We are drawing closer and closer to Atlantis, and its existence becomes less and less impossible.

Prehistorians do not deal with civilizations, properly speaking, but with races. Among these races one of the most remarkable is the Cro-Magnon. This racial type, which presents rather particular characteristics, lived in western Europe and certain parts of the
Mediterranean basin. It is thought that the Basques might be a last branch of this race. Cro-Magnon man, who existed between sixty thousand and ten thousand years before our time, possessed an astonishing degree of art, shown by numerous rock paintings. He knew how to fashion tools and seems to have arrived at a remarkable degree of intellectual evolution. He is credited with being the founder of Druidism.

George Poisson, an anthropologist, thinks that certain Indian tribes, the natives of North America, also stemmed from this race, and he is trying to establish a link between the two continents based on the Atlantis theory. For George Poisson there is no doubt as to the identity of the Atlantans with the Cro-Magnon race. He also points out that several scholars have suggested calling Cro-Magnon man Homo Atlanticus.

Fascinating as his theory is, however, it has not yet succeeded in convincing specialists in the field.
Great Cataclysms

A French engineer, Goard, once advanced the surprising hypothesis that our planet exploded about a million years ago, in the Cretaceous Period.

Before exploding, he explained, our planet was only 5000 miles in diameter and was covered by an unlimited sea. The explosion was provoked by the collision of the solar system with a giant comet, or an "anti-matter hole". The unfortunate planet that travelled between Mars and Jupiter was evidently of too frail a constitution to resist such treatment. It shattered into a thousand pieces which we call asteroids nowadays. The layout of the solar system leads us to believe that there actually was a planet between Mars and Jupiter. At the present time, however, the only thing found in this place is a great number of asteroids. Certain astronomers, Olbers for example, have concluded that these asteroids are the débris of a planet which orbited between Mars and Jupiter. This hypothetical planet is currently known as Olbers' planet, or planet 14 according to Bode's law.

This brutal process of expansion doubled the earth's volume. All of a sudden the crust, which had covered it uniformly under the Panthalassa, broke into several pieces, forming our present continents. At the same time, the speed of the globe's rotation diminished considerably, bringing about by inertia a displacement toward the plane of the ecliptic, according to a law called "dextrogyre". The continents, then, represented different pieces of the same shattered mass. That explains why they fit together like the parts of a puzzle.

Another French researcher, M. Trestourelle, thinks that up until the Tertiary Period, the primitive earth, composed of a heavy mixture of iron and nickel, measured only 6,700 miles in diameter. According to this theory, there was a planet in the sky, instead of
The asteroids; this was the astro-continent, 5,875 miles in diameter, composed of fluid lava covered by a thin shell of granite.

Ten million years ago, this soft astro-continent crashed into our small planet. Imagine what would happen if an egg struck a billiard ball. The shell would break and all the viscous matter in the egg would spread onto the ball, and this is exactly what is supposed to have happened to the earth.

But the strangest result of this theory is that the earth would not have been the site of the origin of life. In effect, this primitive, metallic form of earth was incapable of supporting life and in any case was covered with lava at the time of the collision. Trestourcile thinks that the ancient fossils discovered by the paleontologists came from the astro-continent, not from the earth.

The Earth a pulsating star

The earth is a pulsating star, claims the engineer Horace Havre. Its pulsations take the form of nuclear explosions that occur periodically right under our feet.

At the time of the earth's formation, he explains, the heavy elements clustered in the centre. The earth's core has many radio-active atoms, which pressure prevents from transmuting. Geology tells us, however, that the radioactive elements on the planet are to be found in the crust. The attraction of celestial bodies gradually draws these elements to the surface. When they reach the crust, they transmute, sometimes causing explosions which in turn generate earthquakes.

These transmutations are accompanied by a releasing of helium gas which causes the planet to swell. The earth, then, inflates to the point when the distended crust cracks. Continents split, the gas is set free, the earth returns to its normal volume, and the crust shrivels and folds. A pulsation has taken place, and another will begin.

Horace Havre thinks that we are presently in a phase of dilation and that our descendants will see the planet swell like a balloon until it bursts.
BROWN’S NIGHTMARE

New York is a triumphant metropolis, swarming with activity. Suddenly, there is a hollow, powerful rumbling noise in the distance; a second later, it has swollen to a fearful roar. Before the passers-by have had time to reflect, they see at the end of the immense avenue, standing on end, a thick high wall of water, several hundred yards high. It rushes upon them, carrying along boats, cars, men, and fish. Buildings collapse, and only the most modern skyscrapers can resist the deluge. The flood has swallowed everything.

Some minutes later, nothing more remains of New York. The sea has invaded the coast. Throughout the world, entire regions have been engulfed in these enormous floods.

Is this nightmare a pure invention or simply anticipation? Hugh A. Brown replies without hesitation that it represents anticipation. Everything will happen exactly like this in the not too distant future. Although humanity ignores it, a terrible menace is threatening it.

Brown, a certified engineer from the University of California, claims that this sword of Damocles is the Antarctic ice cap, 8,200 feet thick at its narrowest point and representing 7,200,000 cubic miles of ice. Its centre of gravity is situated 300 miles from the geographic South Pole. It is therefore completely eccentric, as compared to the planet. He also affirms that this mass does not stop growing.

This growth will pursue its natural course right to the moment when the equatorial swelling will no longer be sufficient to re-establish the equilibrium. Then the earth will oscillate in order to find a new position of equilibrium, and it is this sudden movement that will provoke the catastrophe. Brown claims that the last catastrophe of this nature was produced some eight thousand years ago. The pole was at this time situated in Africa, Lake Tchad being the remainder of the last huge glacier. Before that, polar ice covered Hudson’s Bay. The disappearance of these glaciers dates back 11,400 years. Previously it was the region of the Caspian Sea which was covered by glaciers, which melted 18,000 years ago. It can be seen that the periodicity of these cataclysms is very short,
usually lying somewhere between three and seven thousand years. Normally the catastrophe would have already occurred again. It seems certain that another one is imminent.

THE EARTH DISAPPEARS

One hundred and fifty thousand years ago, the sun placed a planet in the world, which we call the earth. The delivery was brutal, and the new star found itself projected some 30 million miles into space. Like its elder brothers, Mars and Jupiter, it then began to turn around the creator of its day. This metaphor is a particularly audacious one, since the young planet did not exactly have days. It did not turn upon itself. From this fact we can gather that one of its faces, the one that was constantly illuminated by the sun, was a furnace, whereas the other one lived in a glacial night. At each revolution the earth went away from and still goes away from the sun.

After some thousands of years, the baby planet attempted very slowly, and with great difficulty, to go round itself. The ordeal was a cruel one. The dark hemisphere, violently exposed to the solar rays, saw its huge glaciers melt, whereas its illuminated face plunged into the night and the cold.

The earth completed its first interminable day, bruised and distorted. But, as stubborn as the child who falls at its first step, it set out again on a second tour.

Five days, lasting some thousands of years, thus followed one after the other. In turn, each part of the globe was plunged into the glacial "night," then into the torrid "day". The "dawn" and the "twilight" were accompanied by worse cataclysms.

The drama, or rather the happy event, took place on the sixth day: the earth gave birth to the moon. It ejected into space an enormous continent which found itself in the southern hemisphere. There remained in its place nothing but an immense, yawning hole: the Pacific depression. The jolting effect of all this caused the Andes, the Alps, and the Himalayas to surge up. Continents completely burst asunder, and the separated parts drifted toward the huge depression in which the waters were swallowed up.

After this dramatic sixth day, the movement accelerated. The day lasted a century, a year, a month, then finally twenty-four
hours. All this happened some millennia before our era; the huge glaciers no longer had the time to form anew. The polar caps stood alone. But the glaciers which formed in the course of “the night” melted most definitely and in catastrophic conditions: this was the flood.

So there we are, the earth dwellers of modern times, quite serene on a ball which at last turns round and round. But our security is deceptive since the earth continues to withdraw from the sun. Each orbit is a little longer than the previous one. Tomorrow, we will be where Mars is now... Mars, which has two satellites. Now it is observed that planets younger than the earth, Mercury and Venus, do not have satellites while those which are older have several. Our earth will therefore be called on shortly to propel a new moon.

A whole continent will suddenly take off into the air, which will prove to be a cruel adventure for the Americans.

They will find themselves catapulted into space and will surely succumb, killed by speed, radiation, and lack of air. For those who remain on earth the situation will not be much more enviable. One can imagine the operation: Africa is sliced in two and the whole western part begins to slide toward the west. At the same time as America, a great part of the water on the planet will have been expelled. The earth is nothing more than an arid, fissured body. Its wounds emit enormous floods of scorching lava while frightful spasms cause mountains as high as the Himalayas to surge up. In a very short time, the inhabitants of the fertile plains again find themselves amongst the eternal snows. The earth, like Mars, possesses only the remnants of life. Such are “the tomorrows howling at the door”, announced by the Swiss Louis Gascot.

COMETS THAT KILL

In *les Femmes savantes*, Trissotin, to make himself appear important, announces to Philaminte that during the night a comet has all but struck against the earth and “shattered it like glass”. The passage of comets was dreaded in ancient times. These wandering stars evidently constitute the ideal destructive agent in man’s dream of the Apocalypse.
Thus Newton’s successor at Cambridge, William Whiston, explained at the end of the seventeenth century that the earth and the solar system had formed in the tail of a gigantic comet. For a time, conditions of life were ideal, and in its overall effect the planet was a terrestrial paradise. But on Thursday, the 28th of November in the year 2349 B.C., God launched a comet against the earth to punish guilty humanity. The first effect of this divine scourge was to unleash a deluge. This unfortunate collision both made the earth’s axis of rotation vacillate and modified its movement. In short, the terrestrial paradise was transformed into this sad earth of ours, with its earthquakes, rigorous winters, oppressive summers, floods, droughts, and sundry other calamities.

Ignatius Donnelly also wished to have a comet of his own. In 1882, he explained to his very numerous readers that the earth had been hurled into space by a wandering star a long time ago. This resulted in poor earth’s being submitted to frightful meteoric bombardments, resulting in a cataclysm of fire and blood, in the course of which entire civilizations disappeared. A veil of gloom covered our earth which, deprived of solar heat, was consumed by ice. In this way the glacial epochs evolved.

In our time, Dr. Immanuel Velikovsky has explained all the traditions, marvels, and miracles related in the Bible in terms of vagabond stars. His explanations also embrace such recorded events as the plagues of Egypt and the immobilization of the sun by Joshua.

Doctor Velikovsky demonstrates to his large audience that the Bible is in fact telling the truth. Narratives can certainly be coloured by subjectivity, but at the base is always real fact. By making use of the mythologies of other people, he has thus been able to reconstruct the history of the world. Here is that history.

**Israel Saved by Venus**

Toward the middle of the second millennium B.C., a comet shaped something like the earth was expelled by Jupiter. It rushed madly through space, soon directing its fierce course toward our planet.

Apart from the meteorites, which fell in a shower of stones, the
star dragged with it a great quantity of hydrocarbons which ignited on contact with atmospheric oxygen. The shower of stones was succeeded by the shower of fire.

The earth, still caught up in the tail of the comet, found itself enveloped in an opaque atmosphere consisting of dusts and hydrocarbons. Night installed itself permanently upon the whole globe. At the same time, the enormous attraction of the cometary mass made the earth reel on its axis and disturbed its rotation. Friction between the internal mixture and the surface provoked a formidable release of heat. The water of the seas began to boil, vermin crawled out of the ground and swarmed to the surface, while hurricanes and earthquakes ravaged the planet.

Drawing ever closer and closer, the comet provoked a fantastic high tide which practically tore away all the waters of the earth. The waves stood erect up to some hundreds of yards in height. In some places, the bottom of the deep seas turned dry. The children of Israel benefited from it, however, since it allowed them to cross the Red Sea. But suddenly, after more violent electrical discharge, the comet extricated itself from the terrestrial attraction, and the waters which stood, fell down. This time they fell most opportune upon the cruel Egyptians who had also wanted to profit from the crossing to recapture their fleeing slaves.

In the middle of the darkness and in a world fraught with terror, the Israelites started their long march through the desert. The earth, which the rays of the sun could no longer reach, was unable to bear vegetation. Happily, the hydrocarbons contained in the atmosphere were condensed in an edible dew which had the taste of honey. The Hebrews collected this in the morning and were therefore able to survive.

During the fifty-two years that followed, the terrestrial atmosphere gradually cleared to the point of recovering its transparency. But the convalescent earth was only beginning its hardships. The terrible wandering star grazed past it a second time. The collision of the cometary and terrestrial magnetic fields arrested the rotation of the earth. Suddenly one day, our planet remained immobile, pulled between contrary forces, allowing Joshua to win his battle. Then, slowly, it proceeded to set out again in the opposite direction. Before the Exodus, the earth turned from east to west. It is
only since the middle of the second millennium B.C. that it rotates from west to east.

Naturally such an operation put the terrestrial globe through torture. Entire continents collapsed and changed places. From the bottom of the seas high mountains leaped up several thousand yards high. The whole earth began to tremble and crack. However, it succeeded in recovering its regular movements, and men proceeded to learn how to live in a world that was totally different from the preceding one. Thus the actual physiognomy of the existing globe, with its mountains and its continents, is not more than four millennia old.

Like Jacot, the author absolutely refutes geological chronology. He considers it erroneous to base a system of dating on radioactive carbon because if the events which he describes really happened, the rate of absorption of carbon by organisms could not have been constant.

The comet responsible for these catastrophes has since become well-behaved, probably because it is Venus, the star of the shepherd. Chained to its orbit, it no longer presents any danger today. To justify the role given to Venus in his reconstruction of the past, Velikovsky notes that besides the proof of a very ancient system consisting of four planets, many traditions possess a legend about the birth of the morning star, whereas hardly anything about any other planet was even known. He also remarks that until the middle of the second millennium, Venus was a redoubtable goddess; afterward, on the other hand, she became a peaceful and accessible goddess. He re-establishes, besides, an ancient and quiet widespread belief claiming that planets and comets were celestial bodies of the same kind.

ICE AND FIRE

With Horbiger, we do not have to do with a dreamer, but with the projection of Hitlerism into science. Hans Horbiger was an Austrian technician who was born in 1860. His doctrine was outlined in 1913 in a work, la Cosmologie glaciaile de Horbiger, by Philippe Fauth, an amateur astronomer who had been inspired by his system. This doctrine, popularized under the initials W.E.L.
The Earth is Alive

(for *Welt Eis Lehre*), was rewarded with an extraordinary degree of good fortune. It did not spread like a simple cosmogonic theory, but rather like a veritable religion. A whole organization came into existence in Germany to propagate the ideas of the Austrian prophet. Actually an alliance was formed between the new philosophy and the Nazi movement. Posters, public announcements, meetings, and a widely distributed publication called *The Key to World Events* all helped to win over a vast public to the new ideas. In this way, a genuine, popular movement was created, which was parallel to the Nazi party but which was also organized and structured to defend and propagate the W.E.L.

Yet those who supported the Horbiger thesis did not content themselves with the usual means of propaganda. Their activity soon took the form of hazing, then of veritable persecution of the orthodox scholars who were accused of defending false "Jewish and decadent" ideas. Astronomers could no longer even teach their courses, and sometimes the Hitler Youth beat them.

The most flagrant example of this intolerance was given by Horbiger himself who in 1925 wrote to all scholars in Germany and Austria: "You now have to choose to be with us or against us." While Hitler was "cleaning up" politics, Hans Horbiger was "sweeping away" false scientific beliefs. The doctrine of eternal ice was to be the symbol of the regeneration of the German people. People were exhorted to align themselves on Horbiger's side before it was too late. Moreover, Horbiger called "enemies" those who did not adopt his system. With the seizing of power by the Nazis, the W.E.L. virtually became the state religion. People even went to the extent of signing acts of faith in the W.E.L. If today we are apt to laugh at this cosmogony, the smile disappears at the thought that a Nazi victory would have transformed it into an official truth, a dogma justifying all persecutions. It is against this historical backdrop that the grandiose and erroneous drama of Hans Horbiger's world was enacted.

In the beginning were fire and ice. Face to face in space were a superstar, several million times the size of the sun, and a planet of ice or likewise colossal dimensions. This body of ice hurled itself on the incandescent star with such force that it penetrated its mass and completely vanished into it. This heart of ice embedded
in that ball of fire evaporated progressively, creating a tremendous pressure. Then came the explosion.

Enormous blocks of ice were hurled across space. Some of them grouped themselves into a ring of fragments closely pressed together; this is the Milky Way. Others formed planets, all of which with the exception of the earth, are made of or covered by ice.

The initial explosion set the whole system in motion, but the planets, displacing themselves in an atmosphere of rarefied hydrogen, were stopped in their course.

A second force ruled the movements of the heavenly bodies: gravitation. The stars attract each other mutually according to their respective mass. And the more they lose their initial energy, the more sensitive they become to that second force. In terms of the cosmic cycle, they all will fall on the one with the greatest mass: the sun. When the ice again penetrates the fire, the cycle will start all over again.

For the moment, the largest planets will "capture" the smaller stars which come into their vicinity. But in its movement around the captor star, the satellite is constantly pulled by cosmic matter. It is therefore constantly approaching the planet and eventually crashes on it.

What was the destiny of the earth in this universe? On three occasions already moons have penetrated our unfortunate earth. Our present satellite is actually the fourth one to have been captured by the earth. The fall of the first three has marked the end of the various geological epochs.

The fall of the first corresponds to the appearance of giant vegetables and immeasurable insects. The end of the second moon witnessed the appearance of great aquatic animals, and also of the first men: the giants. Since the gigantic growth caused by the arrival of a moon in the vicinity of the earth also influences the psyche, the giants also happen to be geniuses. Unfortunately, their brilliant civilization was destroyed by the fall of the second moon. During the period that followed, when the moon was far away, a smaller species developed whom the giants proceeded to civilize. Then the third moon penetrated the earth, and the last
representatives of the race of giants, the master race, disappeared. Humanity then began to degenerate.

All this happened 150,000 years ago. For 137,000 years, the earth had no satellites. Since terrestrial gravitation was not compensated by the attraction of a moon, life was quite simply in a state of decadence. But 13,000 years ago, the earth captured a planet which gravitated between the earth and Mars. This star, larger than the preceding satellites, possessed an earthly nucleus covered by a blanket of 125 miles of ice.

The moon still gravitated too far away from the earth and therefore could not make its beneficial influence felt on the development of life; yet it was coming closer. Under its influence, life would have a fresh start. By mutation, a new race of supermen would be born. Humanity would then rejoice in a new era of splendour as long as our moon did not fall. On this occasion, the projectile world seems so large that humanity will have difficulty in surviving.

In any case, the earth has stopped fulfilling its destiny. After having “digested” the present moon, the next star to be captured will be Mars. But its mass is too enormous. Between the two planets there will exist only a process of grazing, but not capturing. Contrary to appearances, this encounter will be even worse than the preceding ones, because Mars, while passing us, will steal our atmosphere. Besides, its attraction will dislocate the crust of the earth, releasing all the internal heat of the globe. All the water of the planet will evaporate. Finally, earth in space will be no more than a dead and desolate pebble, which will eventually throw itself into the sun.

THE BROKEN MOON

When we talk of the moon falling on the earth and continents being formed by the debris of a planetary shell, it all smacks of science fiction. Yet a Swedish physicist, a genuine scholar called Hannes Alfven, has recently put forward a theory which closely resembles the systems of Trestourelle and Horbiger.

Professor Alfven holds that the moon constitutes an anomaly in the solar system. It is too large. Its mass is 1/81 of that of the
earth while the proportion for the satellites of the other planets is in the order of 1/1000. With these conditions, the scholar was led to believe that the moon is an ancient planet captured by the earth. When it became a satellite, the moon was still much larger than it is today, and it turned at a distance of 2.5 earth rays. Now a law of physics called Roche's law would have it that a solid satellite cannot approach too close to its planet without being shattered by the gigantic tides which it suffers. In the case of the moon, the disintegration point was 2.88 earth rays. Thus the planet which we had imprisoned broke up. All the superficial layers flew off in a series of explosions and only the nucleus remained. Huge rock fragments fell onto the earth where they formed continental bases; others fell back on the moon, giving it a pre-Apocalypse appearance. Still more were hurled into space.

At the time of this catastrophe several hundred million years ago, earth still showed nothing more than traces of life. Now the violence of the shock was such that the fragments of the terrestrial crust were hurled into space. The traces of organic life in these fragments, which fall back again today onto our planet in the shape of meteorites, are thus explained.

This theory is so recent (1963) that one can only surmise the acceptance that will be accorded it in the scientific world. It is nevertheless a strange fact that one of the intuitions of Horbiger's cosmogony today helps to elaborate a scientific hypothesis.

LESSONS OF A PILGRIMAGE

"Invent! It is not a festivity lost at the bottom of your memory..." wrote the poet Robert Ganyo. His could well be the conclusion of our unusual pilgrimage to the museum of different lands. In this respect it is only fitting that we pay tribute to the exuberant flowering of the human imagination, and we should remember that many of the "deluded" of the earth also happen to be its greatest poets. Their artistic creations, far from constituting a shameful blot on human history, should be considered as a normal means toward a full flowering of human possibilities. We should nevertheless be careful to keep them in their proper sphere, which is that of the imagination and not of science.
Poetic visions sometimes create enormous human obsessions and consequently are pregnant with meaning. The earth has comport itself like a photographic plate revealing the hidden personalities of those who have wished to recreate it. Geocentrism, the corresponding flat earth theory, for example, can be interpreted as a defensive reflex against the Pascalian anguish of the two infinities. This is the denial of a universe which manifestly was not made in the measure of man, and which can no longer be comprehended by good common sense.

The vertigo of the cataclysm seems to convey a denial of human evolution. It evinces a deep-rooted pessimism in the face of human development. In the unconscious, the catastrophes generally correspond to forms of divine punishment.

Furthermore, if one lends to humanity a linear destiny, and not a cyclical one, if, for example, you still grant it another billion years of existence, the thought of its possible progression is terrifying. The dizzy dream becomes a nightmare, a destructive cataclysm to some, while for others it is a reassuring prospect.

One must still reconcile certain deluded visions of man’s irresistible penchant for drama, violence, and death. The tragic world of Horbiger corresponded perfectly to the Nazi universe which itself embodied certain themes from Germanic mythology. Affinities of the same kind could be found between Horbiger’s cosmogony and the Aztec vision.

Finally, through the most distant terrestrial myths can be made out an image of the earth which is very different from that of scholarly manuals. Our planet becomes a teeming organism, where everything changes endlessly, fuses, separates, evolves, dies, and is reborn. This earth, which for “civilized” man is no more than a great pebble is sensed by the primitive like a living being so long as it comprises dynamic processes in action. Very strangely we shall see that science more and more tends to stray from the first conception of the earth in order to return to the second.
10 / The Earth in the Universe

To make a proper study of the earth, we should really approach it from a distance. For despite the advances made by our astronauts, the imagination is still the most effective means of providing the necessary scope and vision to examine our birthplace in the universe.

Let us therefore leave the solar system, even our galaxy, and look at all this from a truly astronomic vantage point at a distance calculable in millions of light years. From this observatory, even our famous Milky Way loses all claim to originality, being but one galaxy among millions of others. A telescope trained on the depths of the cosmos would reveal to us a whirling lens-shaped mass; from its centre come long whorls which roll round it in the direction of the rotation. It is the classic picture of a galaxy which one may see in all astronomical works. This commonplace world of stars is, however, a fair size: 100,000 light years in diameter and 10,000 in depth.

How are we to recognize the sun among the two or three hundred billion stars that make up the Milky Way? We cannot hope to spot it by some obvious peculiarity. From its size, mass, brightness, and position it is the perfect example of the common star. On diagrams classifying the stars in terms of their different characteristics, we find it always in a kind of central position, in the medium weight category, precisely where the anonymous stellar mass crowds together. It is not a nova with a glittering surface, nor a white dwarf with prodigious density, nor a variable that makes disturbingly capricious leaps, nor a red giant: it is a yellow dwarf in the main series, something you might call an “Everyman” in the world of stars.

For a long time, a kind of cosmic chauvinism had made us place the sun at the centre of the galaxy. We had to dislodge it
from that noble position to put it back in its true place: lost in a
galactic sea, thirty thousand light years away from the centre.
Let us face the inevitable; if there is anything notable in the human
phenomenon, it is not its position in the cosmos.

Looking at the sun from a more reasonable distance, we will
notice first a complex system of stars. From the point of view of
Sirius, it is likely that Jupiter and Saturn look more like com-
panions to than satellites of the sun, even though their diameter is
from ten to twelve times smaller than the sun’s. Undoubtedly we
must choose between these two giants if we are to distinguish an
important personage in the planetary family. By comparison the
other planets would seem very puny. Saturn could hold 742
Earths and Jupiter, 1,310.

AN ANONYMOUS PLANET

The Earth, on the other hand, seems to present no notably
peculiar features. Of the nine known planets it is fifth in size, third
in distance from the sun, fourth for the number of its satellites and
fifth for mass. Its rotation is faster than that of Mercury, Venus,
Mars, and Pluto, but slower than that of the rest. In short, from
all its characteristics the Earth is an ordinary, medium, and rather
anonymous planet.

At best we can note the originality of the pair which it makes
with the moon. The relation between the mass of satellites and that
of their planets is generally in the order of one to one thousand.
The twelve children of Jupiter together represent only \(1/6000\) of
its mass. The satellite is therefore hardly more than a pebble, and
its eternal patrol has no influence on the star which imprisons it. In
the case of the moon it is quite different; its mass is \(1/81\) of the
earth’s. The proximity of another important heavenly body
disturbs the life of our planet considerably. It would therefore be
more proper to speak of it as a twin planet than as a satellite.

For a Martian astronomer, Earth must have the graceful look
of a phantom comet. The latest astrophysical observations have
revealed that our planet is lengthened by a long tail very like that
of a comet and wears a white halo of helium, like a luminous
aureole, carving it out on a background of black cosmic space.
AT THE CENTRE OF A WHIRLWIND

Let us suppose for a moment that we could escape the limitations of our senses, that reality could no longer hide from us in the micron, or in the light year, or in the thousandth of a second, or in a billion years. Let us suppose that we see everything: waves, corpuscles, heavenly bodies, and atoms. How then would the solar system look to us?

We would in fact experience a strange transformation. What we call “the sun” is no more than the heart of a star whose atmosphere stretches out for hundreds of millions of miles. From the incandescent earth, ceaselessly rocked by thermonuclear explosions, there come vague waves and floods of particles that fill space with what we may call “solar breath”. Our “interplanetary void” would now seem like an ocean traversed by waves and currents. Sometimes an aerolite speeds through space like an arrow. We never see these aerolites; for they are not comets, but cosmic rays.

At the centre of the whirlwind a whitish mass spins and palpitates: the earth. In the health-giving pool of the solar world, it draws matter and energy endlessly. It is indispensable to recognize this great revolution in the space era: that we do not live next to, but in the sun. This is a major revelation, for as soon as astrophysicists discovered this solar omnipresence, other scientists saw its influence permeating the most diverse fields: biology, chemistry, geology, geophysics, etc. Science recognizes the sun’s imprint everywhere.

“We have lost the sun and the important thing is to find it again; the rest will follow”, wrote the great nonbeliever, D. H. Lawrence. Today we are in the process of rediscovering the sun, not in the shape of divinities such as Aton, Râ, Samash, Helios or Mazda, but in its real form. This is in fact much more fascinating than seeing it as a mysterious, glittering presence worshipped with an attitude of awe. This star, once adored by so many civilizations, then reduced to the rank of a cosmic projection, appears today as the veritable dictator of earthly life.
OUR NOURISHING STAR

We live in the sun, and we are slaves to its slightest whims. It is inevitable, then, that a study of the earth must begin with an examination of the sun.

The sun is an ordinary star. Practically, this means that it is a gigantic nuclear pile of ingenious simplicity, since it is composed solely of an enormous ball of plasma (865,400 miles in diameter). Our atomic piles which draw energy from the fission of heavy atoms are by comparison very imperfect machines. For years researchers tried desperately to emulate the sun’s production of energy by the controlled fusion of hydrogen nuclei. Although it is indeed possible to obtain this reaction, it cannot be controlled, for each time it is produced in a certain quantity it causes a terrible explosion. Yet each second the sun turns 500 million tons of hydrogen into 496 million tons of helium and does not explode. Why?

The secret of this miracle rests in a dynamic equilibrium set up on all levels of the star between the pressure of gravity, which tends to compress the plasma to the centre, and the pressure of radiation produced by nuclear fusion, which in turn tends to expand it. So the sun’s mass is worked by both a centripetal and a centrifugal force. The interplay of these opposing forces prevents the reaction from setting off and ensures the efficient functioning of the solar mass.

The stellar nature of the sun dooms it to suffer the fate common to all stars. Their bodies are not unchangeable; they evolve according to a well-defined pattern. With five or six billion years behind it, the sun seems to be in its adulthood, with stellar old age approaching. This state of decrepitude does not augur well for us. A yellow dwarf today, the sun is expected to become a red giant before contracting and ending up as a white dwarf. Becoming a red giant means that the sun is going to start expanding and that its temperature and radiation are going to increase considerably. The results are easy to foresee. The earth will experience conditions like those which exist on Mercury today. In this infernal furnace all life will vanish, and the human adventure will draw to a close. Astronomers are not in agreement as to how much time
we have left. According to some the heating up of the sun could begin in a few thousand years, while others think we still have several billion years ahead of us. Nor can we any longer exclude the possibility of an imbalance in the sun’s mass which would blow it up. The sun would then become a nova and the earth would be set on fire as in the visions of the great cataclysm.

At the present time this marvellous thermonuclear centre hurls into space 380,000 billion million kilowatts each second, corresponding to the dematerialization of four million tons of matter. Every second, as we have said, the sun produces 496 million tons of helium from 500 million tons of hydrogen. The 4 million tons of matter that disappears is converted to energy according to the matter-energy equivalence established by relativity. The conversion of hydrogen into helium is brought about in the heart of the star by a temperature of 15 million degrees under the pressure of a billion atmospheres. Here the plasma reaches a fantastic density which cannot be measured against those obtainable in the laboratory.

The face of the sun as we see it is called the photosphere; it is the layer at which the star shines in visible light. But the sun extends farther, well beyond the photosphere, in the chromosphere and the corona which, according to the latest theories, should be considered as encircling practically the whole solar system as far as Saturn.

These surface layers are characterized by a decrease in density and a great increase in temperature. Matter is rarefied so that “densities” soon exist which we should unhesitatingly call “void” in the laboratory, but the astro-physicists have shown that rarefield matter constitutes a medium just as qualified as the solid or liquid states.

From the centre of the sun to the photosphere the temperature decreases at a regular pace from 15 million degrees centigrade to six thousand. Then it increases again, reaching 20 thousand in the chromosphere and one million in the corona.

This increase in temperature still has not been explained with any certainty. At 6,000 degrees centigrade the photosphere transmits light to us; the chromosphere, which is hotter, will give out a harder form of radiation. The study of its spectrum has shown that
it emits a hard ultraviolet radiation chiefly in the Lyman-Alpha hydrogen band.

The corona has long been a tormenting enigma for scientists. The spectrograms show twenty-four unidentifiable rays. Does a body unknown on earth exist on the sun, a body not listed on the periodic table of elements? We have spoken tentatively of "coronium," and it was only during the international geophysical year that positive light could be shed on this problem. The mysterious radiation was being emitted by familiar substances like iron and calcium which, as a consequence of the abnormally high temperature of the corona, lost their electrons and sent out radiation on the scale of feeble X rays.

But this temperature can bring matter to such a degree of excitement that it escapes the sun's field of gravity and moves off into space. It is this constant corpuscular evaporation that forms the famous "solar winds"—a monumental discovery of the space era—and expands the solar corona to an inordinate degree. The loss of matter from the sun is enormous: roughly 600 million tons per second (a calculation based on the enormous projections of matter at the time of the eruptions). At this rate the star must have already lost five per cent of its mass since it formed.

Interplanetary space is therefore quite different from the interstellar void and holds matter at a rate of 1,000 particles per cubic centimetre. The interstellar void apparently holds only one particle per cubic centimetre.

A STAR LOSES ITS COMPOSITION

All these solar phenomena are observed in a state of permanence, and constitute the activity of a calm sun. Yet the star that gives daylight is never completely calm. In fact, it is sometimes terribly disturbed.

On February 9, 1958, at the solar observatory in Boulder, Colorado, the astronomer on duty was insufficiently aware of the dangers that the sun-god's wrath means for us. In the United States all observations concerning the sun are centralized at this observatory. On the day in question the astronomer received several pieces of information indicating that an enormous solar
explosion had occurred. Since conditions for observing in Colorado were unfavourable and since he could not himself trace the phenomenon, he decided rashly that this solar explosion could have no possible repercussions in our atmosphere, and consequently did not alert anyone.

Twenty-eight hours later magnetometers throughout the world began to spin. At Hiraso in Japan one instrument was shaken so violently that it broke down. Radio communications between the Old and New Worlds were abruptly broken off. Airplanes in flight lost contact with the ground and tried to relay messages between themselves until they could get close enough to the airports to transmit again. At the same time, the ionosphere was crisscrossed by currents of several million amperes. The electrification of the atmosphere activated interrupters, plunging entire towns into darkness. It had a fading effect on the transatlantic cable—all the more irritating because there was no other link between America and Europe. As a contrast, Mexicans, Cubans, Australians, and Japanese saw their skies embellished by superb aurora borealis (or australis), a rare phenomenon in those latitudes. This shows how fragile our earth is when confronted with the sun’s anger.

The latest theories see in chromospheric explosions a mechanism quite close to that which we are trying to develop in the laboratory to achieve controlled fusion. The Soviet astrophysicist Severbyi thinks that the magnetic field, locally intense, strongly compresses the unstable plasma causing a heat increase of several million degrees which eventually unleashes the thermonuclear explosion. The Americans have christened it the “pinch effect”.

Radio emission from the sun was discovered in 1942 by English soldiers who were searching the sky with a radar installation at Southampton. They suddenly located a distant object which was nearly motionless, yet which reconnaissance planes could not pick up. At nightfall the mysterious object disappeared from the radar screen, but it reappeared the following day. For a long time the British military authorities wondered what this unknown observation device was that the Germans had sent up. Finally the physicist Appleton, learning of their problem, explained to the radar men that they were listening in on the sun. The mysterious
spot on the radar screen was simply a disturbed point on the sun’s face which was dispatching radio waves.

Today we are aware of our subjugation to our solar tyrant. Any solar eruption is instantly announced, and the necessary precautionary steps are taken.

GIGANTIC SPOTS

The sun’s magnetic field is generally depicted as two gigantic circular tori revolving around the rotation axis, one in the northern hemisphere and the other in the southern hemisphere. The tori turn in different directions.

We see solar activity in the form of spots and eruptions. Sunspots are essentially magnetic phenomena. They usually appear in pairs and form a magnetic link, one constituting a south pole and the other a north pole. To the observer they look like gigantic, gloomy craters some of which could hold several earths. After some weeks they disappear. An intense magnetic field prevails in these spots which is accompanied by a diminution of temperature and pressure. Between the two spots the plasma is caught in the lines of force of this formidable magnetic field. It is probably this that ultimately causes the thermonuclear explosion which seems to be the origin of the eruption.

When the temperature reaches several million degrees an explosion occurs, hurling fantastic jets of plasma up to several thousand miles in length.

From the nucleus, powerful electromagnetic radiation is released, including all wave lengths from X rays to radio waves. Some accelerated particles in the solar magnetic field even become weak cosmic rays. Finally a flow of particles (protons and electrons) is hurled into space. This corpuscular projection forms clouds of plasma possessing great coherence, for they carry into space the magnetization caused by the solar magnetic field. Thirty hours after the explosion, the flow arrives in the vicinity of the earth. The inhabitants of the subpolar regions then see the appearance of brilliant aurora borealis.

The magnetic cloud will indeed disturb the upper atmosphere, compressing it into the hemisphere which faces the sun, and
unleashing magnetic storms on the whole planet. Thus our atmosphere, that is our earth in its entirety, is compressed and exploded to the rhythm of solar activity, throbbing endlessly under this awesome cosmic breath.

The Eleven Year Rhythm

This solar activity varies constantly in time: the sun passes through alternate periods of disturbance and calm. This alternation follows an eleven year rhythm, though the reason for this periodicity is not yet known. The cyclical character of this solar activity is extremely valuable, however, for it lets us suspect relationships between certain terrestrial and solar phenomena. Eleven years: we shall often come across this figure again, and usually in a most unexpected way.

For the moment let us say quite simply that the sun sends us, according to a variable rhythm, an electromagnetic flow including all kinds of waves, and a corpuscular flow composed of protons and electrons as well as neutrons. Some astrophysicists think that between the two celestial bodies there takes place by uniform conduction a slight process of heat transference.

This marvellous atomic pile is very dangerous, and we are lucky that the atmosphere provides us with very effective protection. The interplanetary traveller will not enjoy such protection, however, and for this reason he will probably have to wait a few more years before venturing forth to conquer the cosmos.
The possibility of a double rotation of the earth, upon itself and round the sun, had seemed an unlikely feat to the contemporaries of Aristarchus and Copernicus. How would they react to the teachings of modern astronomers who distinguish no fewer than fifteen simultaneous movements in the earth’s “flight plan”?

The celestial bodies’ elegant waltz is simple and uniform only in the eyes of the layman. Astronomy has shown quite the contrary, that our planet, tugged in different directions by opposing forces, limps and reels in its orbit. Like a poor dancer, it does not keep time; it is sometimes ahead of the music, sometimes behind it. It is true that the examiners who render this severe verdict do not overlook a quarter of a thousandth of a second in twenty-four hours. But celestial mechanics is an exact science, leaving nothing to chance. Each anomaly is only evidence of a phenomenon to be explained. While doing continuous research into possible time lags between theory and observation, astronomers have succeeded in reconstructing exactly our fantastic ride in the cosmos.

Like its fellows, our galaxy is fleeing toward the limits of the universe, taking us along at a speed of several hundred miles per second. But the Milky Way is also a gigantic carousel in which the sun turns at 168 miles per second, making a complete revolution 250 million years. Furthermore, the solar system does not always stay in the same position in the galaxy. In fact it is moving toward Vega at twelve miles per second.

The earth plays an active role in the drama of the planets. Despite first appearances, the Keplerian orbit which it describes around the sun is never the same. It alternately moves away and comes nearer without ever staying in place. In fact the orbit tends toward the perfect circle from which it never strays far. The
great axis of this ellipse never stops moving, making a complete revolution in 21,000 years. The angle which the plane of this orbit, called ecliptic, forms with the celestial equator is no longer constant. The intersection line of these two planes also changes position constantly.

It is known that the earth leans on the ecliptic; its rotation axis is presently inclined at $23^\circ 27'$. But this angle is capable of opening up to $24^\circ 27'$ or closing to $21^\circ 59'$.

The direction of this axis in regard to the stars undergoes other much more important variations because of precession and nutation.

Schematically, the mechanism of these two disturbances is simple and can be explained by the properties of the gyroscope. Both a children’s toy and an irreplaceable precision instrument, the gyroscope, a flywheel turning on an axis, points faithfully in the same direction as long as it is not disturbed in its rotation and the direction of the forces which we want to impose on it is not changed. Its reaction to traction always takes place at right angles.

The earth is nothing more than a gyroscope. Lunar-solar traction tends to place it upright on the ecliptic plane. If it were arrested, it would react by straightening up; as it turns, the gyroscopic transformation of the movement makes its axis swerve until it describes an immense cone.

**A COMPLEX MOVEMENT**

Unfortunately the sun, moon, and stars never agree to pull together on our planet. Their actions sometimes unite and sometimes oppose so that the earth’s axis, instead of following a simple cone, goes through a much more complex movement.

At this point let us retain only the two principal component forces of this movement: precession and nutation. The first of these movements and by far the most important was discovered in antiquity by Hipparchus. It causes the earth rotation axis to describe a cone of $47^\circ$ every 25,695 years. Thus the earth’s axis never points in the same direction on the celestial sphere. The Egyptians had Dragon Alpha as their polar star, while in a few
thousand years our descendants will take their bearings on Alpha Cepheus.

By comparison nutation causes a very secondary form of movement, with a degree of amplitude of 18" for a period of 18 years and 8 months. Astronomers have calculated that every eighteen years and eight months nutation causes the earth's axis to describe an ellipse with a large axis corresponding to an opening of 18" 42, while the smallest corresponds to 13" 72.

These very vague notions of celestial mechanics show us that the earth is never in the same place in the universe and that, relative to the sun, its position changes from one year to the next. This may have very important consequences for future climates. Certainly it is most interesting to speculate on an eventual explosion of the sun, but it is more essential to know that the sun will continue to provide us with summers in millennia to come.

On this subject astronomers have come up with most disturbing calculations. When the eccentricity of the terrestrial orbit and the inclination of the axis of rotation reach their maximum value at the same time, the mean temperature of the planet experiences variations in the order of ten degrees centigrade. Some scholars, like Professor Gamow, attribute glacial eras to these variations in our astronomical position. For Gamow, the important climatic variations, due solely to the laws of celestial mechanics, follow a cycle of about 100,000 years. But glacial periods can come into being only in periods which follow the rising up of mountains, allowing the spreading out of glaciers because of the pull of gravity. During the greatest part of its history the earth probably had no marked surface variation, and glaciers would not have been able to spread.

Geologists generally are not willing to concede that the earth's crust has known "flat" eras and "wrinkled" eras. It would seem rather that the growth and wearing away of mountains have never stopped, contrary to previous belief.

On the geologic scale these fluctuations are very rapid, but they are nevertheless calculated in thousands of years, which gives us hope for some respite before the next glaciations.
THE EARTH IS NOT ON TIME

As it turns upon itself, the earth has given men a certain rhythm of duration, which was first materialized by the displacement of the shadow of the gnomon on the ground. The first measures of the day—and then of the hour—were based on the successive journeys of the sun to the meridian. Advances made in the watch making industry showed that the duration of the day thus calculated could vary by several minutes. This time-lag is brought about by the earth’s changes of speed on its orbit, in conformity with the law of areas. In order to have a more certain time standard, astronomers then measured the day using stellar data. In this way, they obtained a much more constant unity: the sidereal day, which lasts 23 hours, 56 minutes and 4.09 seconds.

Thanks to the development of atomic clocks in recent years, scholars have succeeded in measuring time without celestial data. Accuracy is such that, from now on, when the movement of a star appears to lag in relation to theoretical calculations, astronomers know that it is not a case of failure in their clocks, but on the contrary, that it is a disturbance in the celestial mechanism. The conquest of precision in the measurement of time can today be considered as complete. It has been marked by three stages.

In 1927 the balance clock was replaced by the quartz clock, in which crystals subjected to alternate currents vibrated according to a period in the order of one hundred thousandth of a second.

In 1949 the atomic clock—properly speaking, the molecular clock—made its appearance. Its inventor, the American Harold Lyons, christened it the Atomicron. It used the oscillations of nitrogen atoms in a molecule of ammonia (NH₃). The frequency obtained was 24 million vibrations per second, and it was exact to one second per century.

Last of all, real atomic clocks were developed using the principles of hydrogen masers. They are based on the oscillations of the electron in the hydrogen nucleus. The frequency attained is nearly 1,500,000 megacycles, sixty times superior to the Atomicron. A clock has just been constructed on this principle at the Harvard University laboratory. It should reach a precision of 10¹⁵; that
means that its variations will not exceed three seconds in one hundred million years.

The Chaldeans proved the rotation of the earth was not uniform. The Babylonian astrologers were particularly careful observers of celestial phenonemena. Every night they would watch the sky and record their observations on carefully kept tablets. Some of these tablets have been recovered in archaeological excavations. On one of them were the words: "On the sixth day of the month of Sibellu, in the seventh year, day changes into night." In twentieth century language, it said that there was an eclipse of the sun on July 31, 1062 B.C.

Astronomers can both predict the date of future eclipses and calculate that of previous ones. J. K. Fotheringham found that an eclipse did take place at that time, but that it could have been only partial in Babylon. The tablet mentioned day changing into night; the eclipse had therefore been total. According to the calculations, this anomaly represented a time lag of four and one half hours.

There was nothing abnormal to Fotheringham in this result. It simply confirmed a phenomenon known since Newton: the slowing down of the rotation of the earth.

Our earth turns less and less rapidly and the duration of the day constantly grows longer. The slowing down is caused by the friction of the ocean masses set in motion by the tides. It lengthens the day by 0.00164 seconds per century.

It may seem a waste of time to bother with a phenomenon of such tiny dimensions. It is true that this modification in the length of the day is totally imperceptible on the scale of a human life, but it has assumed considerable proportions on the scale of the earth's history.

Calculation shows that the year must have had 412 days 500 million years ago. Proof of this fact was given in 1962 by the American geologist John Wells who has found and deciphered a sort of logbook carefully kept by the earth in the course of the geological ages: coral fossils. In a study of the polyps it has been established that cyclical modifications occur, corresponding to the change of the seasons. It is therefore possible to determine the
work carried on by the corals in the space of a year. On the portion of the polyps corresponding to one year’s production we notice by microscopic study a series of several hundred striae, alternately dark and light. To Professor Wells, these striae correspond to the daytime and nighttime secretions of the corals.

We can immediately see the possibility offered by this observation. By studying polyp fossils, it becomes possible to count the days in the year in the Primary Period. Professor Wells has been able to depend on polyps to trace back to the Devonian (almost 350 million years) a number of striae varying between 385 and 400. Remembering always that the method is very new and needs confirmation, here is proof that days were clearly shorter and so there were more of them in the first geologic periods.

But even allowing for slowing down, we notice that the earth does not turn regularly. These variations have been studied particularly by French astronomers. The most exact observations of diurnal movement are obtained by marking the moon’s movements in relation to stellar data. The precision reached in these measurements is such that the surface features of the moon must be taken into account.

The most effective means of observation in this field is the astrolabe developed by the former director of the Paris Observatory, Professor Danjon. In this apparatus all human intervention is replaced by electronic devices.

Some variations result from the changing of the seasons which causes the displacement of enormous masses of air. The duration of the day grows progressively longer in autumn and decreases in spring. Winter days are therefore about 1.5 milliseconds longer than summer days.

If we make allowance for the seasonal slowdown, do we finally obtain a regular duration for the day? Obviously this would be too simple. On February 23, 1956, astronomers at the Paris Observatory declared that all of a sudden the duration of the day has just increased by in/1000 second. The same day the face of the sun was set on fire by a fearful eruption. In July 1959 a new slowdown occurred: it is held that, as in 1956, an enormous solar eruption took place. So it would seem that the sun can slow the
earth’s rotation by spewing out fire, but these very delicate observations are not recognized by all astronomers.

The mechanism of the phenomenon remains unknown but it is thought that it follows electromagnetic disturbances caused in the upper atmosphere by the arrival of clouds of solar plasma. These disturbances must have repercussions on the electromagnetic state of the globe.

Yet it does not seem possible to attribute all unforeseeable disturbances in the earth’s rotation to the sun. The duration of the day experiences other variations lasting for periods of several years. It diminished by a few thousandths of a second toward 1870, then it increased in the same proportions at the beginning of the century. It is undoubtedly the task of geophysicists rather than of astronomers to find the causes of these changes in rhythm.

THE EARTH IN SEARCH OF ITS EQUILIBRIUM

With precession and mutation, we have considered variations of the earth’s axis in relation to celestial data. But until now we have supposed that the axis was fixed in relation to the globe itself. Briefly, we have impaled the earth on a huge stake ending at the polar star. This stake, as we have seen, is constantly moving.

If this is so, the position of the poles would have to be changed on the earth’s surface. As latitudes are calculated starting from these points, their displacement must make them vary on the general mass of the globe. It is just this fact that very exact measurements help us to discover. The poles do not hold in place, but tender to wander.

This “wandering” does not take the poles very far: fifty feet at the most from a middle point. But here too the small dimensions of the phenomenon do not change its reality.

Scholars have succeeded in retracing the uncertain whorls described by the poles from the beginning of the century. These movements seem to be composed of several superimposed cycles. The total effect presents numerous irregularities.

This “wandering” corresponds to a never-ending effort on the part of the earth to find its equilibrium. In fact, the globe’s rotation axis never corresponds to its equilibrium axis (its axis of inertia)
which itself must pass by its centre of gravity. If we consider the totality of planet, crust, hydrosphere, and atmosphere taken together, we see that matter is not distributed uniformly from the centre and, further, that this distribution varies endlessly. The bowels of the earth are traversed by huge, infinitely slow currents. On the surface erosion carries matter from the continents to the bottom of the oceans. When the polar ice melts, the load shifts toward the equator. Whole continents rise or fall. In short, the earth should not be regarded as a perfect and immutable monolithic sphere but, on the contrary, as an irregular mass, working forever to compensate by readjustments for deformations which keep reappearing in order to maintain its equilibirum. By this effort the earth tries to make its axes of rotation and inertia coincide, but since the latter constantly varies, our world will never be in equilibrium.

The big question is whether this polar dance finally expresses itself by a continued movement in a determined direction. The poles do stray. Is the straying accompanied by drift? The question still remains unanswered. However, certain observations would permit the suspicion of a displacement of the North Pole toward America, at the rate of 3.15 inches per year. Whatever is the case, it is the totality of the mechanisms of the “earth machine” which is involved in this incessant struggle for equilibrium.

PENDULUM PROVES THE EARTH’S ROTATION

At the beginning of the century two thousand people gathered at the Pantheon in Paris, among them all the scientific élite of the time. Fixed to the cupola was a pendulum 200 feet long, held to the wall by a string. A small sand embankment had been laid out in a circle on the ground. The Minister of Public Instruction, M. Chaumié, solemnly burnt the string and off went the pendulum for a first swing. On its way it made a notch in the sand. Once, twice, ten times it swung, and soon the bystanders could verify undeniably what man had wanted to see for centuries: the earth in the act of turning. To be perfectly exact, let us say that the spectators saw that each notch made in the sand by the passing pendulum was always a little to the right of the one before.
Actually it was the entire pendulum which was carried off to the right as the work of the earth’s rotation went on. Why say that Foucault’s pendulum proves the earth’s rotation? Because the pendulum would not deviate toward the right if the earth did not move.

The centrifugal force developed by a body in rotation is not as simple as is commonly believed. Properly speaking, a complementary force is added to centrifugal force, operating at right angles to it. This second force actually exerts itself only on a body which is both in motion and also subjected to centrifugal force. In the northern hemisphere it results in pushing all bodies in motion to the right. This law is by no means theoretical, and every artilleryman makes the corresponding corrections. It is this complementary force, called the force of Coriolis, which pushed Foucault’s pendulum to the right. As the earth turns, this force itself turns and pulls the pendulum in a complete rotation. If the earth did not turn, the force of Coriolis would not exist, and the pendulum would always remain in the same plane.

Theoretically this phenomenon could have been made plain in a much simpler way. If you fill with water a spherical tank with the drain in the middle, the water will form a whirlpool as it empties. In the northern hemisphere this whirlpool will turn to the right—and in the southern hemisphere, to the left. In the same way if you observe the river beds in the northern hemisphere, you will find that erosion is greater on the right bank.

We were obliged to recall Foucault’s experiment, which after all is only of historic interest, because his pendulum came back in fashion on June 30, 1954. Professor Emile Allais of l’Ecole des Mines happened to be watching an improved version of Foucault’s pendulum—the paraconical pendulum—when he suddenly saw it go wild.

What had happened to cause the plane of oscillation to change abruptly? An eclipse of the sun had taken place. The disturbance had corresponded exactly with the occultation of the sun by the moon. The experiment was surrounded by the most rigorous scientific precautions, but the inexplicable fact remains: when the moon hides the sun, the pendulum goes wild.
Since then, experiments carried on at Griffith Observatory in Los Angeles have shown that Foucault's pendulum cannot bear lunar eclipses either. This is much more extraordinary.

Lastly, if we are to believe the Argentinian scholar, Guido Buffo, the pendulum will be disturbed before each seismic crisis. Buffo has made more than 100,000 observations in the last 13 years. If this phenomenon is confirmed, we will have to concede that earthquakes are preceded by a disturbance of the gravitational field. For the moment it seems quite inexplicable. One thing seems established: the solar gravitational field is in no way affected by eclipses. We know that gravimetric measurements reach such a high degree of accuracy that the influence of solar attraction can be shown. Now, the most sensitive gravimeters do not vary during the occultation of the sun by the moon. Solar gravitational waves seem to cross the moon with no difficulty. This observation only makes Professor Allais's experiment more mysterious. Could there exist an unknown field of force dependent on celestial phenomena? Existing information does not lend itself to such an hypothesis.
When man had only sacred texts at his command to ascertain the age of the earth, he was unaware of irritating uncertainties. Thus in 1656 James Usher, an Irish bishop, announced that the world was created on Sunday, October 22, in the year 4004 B.C. This estimate was inserted as a marginal note in the King James version of the Bible and was almost added to the revealed truths. The vice-rector of Cambridge University, John Lightfoot, inclined rather toward Thursday, September 17, at 9 o'clock. In the same period, in accordance with methods equally certain, Thomas Burnet calculated that the deluge occurred 1,600 years after the creation and that, in that interval, 10,737,418,240 individuals had seen the light of day. The Hindus, for their part, took a broader view, and Vishnu Pavana has us living in the 1,972,949,050th year since the creation of the world, the whole history of which constitutes no more than one day in the life of Brahma.

In the last century scholars questioned these over-exact dates. They considered that the traces they observed on the surfaces of the earth were the wrinkles of old age and not scars of recent catastrophes. They thought they had found an effective method of dating by studying the salination of the oceans from which they uncertainly concluded the earth's age to be in the neighbourhood of 100,000,000 years. By great luck, at the beginning of the century, a hidden time-piece was discovered, locked in the rocks themselves. The method for use was very simple.

The earth's crust encloses radio-active materials, that is, elements whose atoms are unstable. The nucleus of an atom contains protons with a positive electric charge. Since charges of the same kind repel one another, a nucleus could not normally contain more than one proton. But in the heart of the nucleus there is a cohesive force superior to the electric forces of repulsion. How-
ever, it can happen that this nuclear force cannot counterbalance the mutual repulsion of the protons. The nucleus then expels protons until it reaches a state of equilibrium, that is to say, a state of energy in which the nuclear forces of cohesion will again have the upper hand. It is this loss of protons that constitutes the natural radio-activity that is found in rocks.

The rhythm of disintegration varies considerably from element to element. But each radio-active element has a disintegration rate of its own which never varies. If you take a gram of strontium 90 you can be sure that, come what may, you will not find more than a half-gram in thirty years’ time. This time lapse necessary for half of the mass to disintegrate is called the period of the element. It is independent of the mass of matter assembled at the outset.

As it disintegrates, the radio-active body forms known by-products. By measuring the mass of these by-products, we can calculate the amount of radio-active matter present at the beginning. Thus we need only to see what proportion has disintegrated to know how much time has elapsed since that beginning.

The important thing is to find an element that is widespread in nature and that has a period that is not too short and not too long. At the moment there is a choice of several radio-active clocks.

The first clock used was based on uranium, which produces helium and lead as it disintegrates. The release of helium corresponds exactly to the overflow of excess protons. The protons are expelled in pairs called alpha particles which are nothing but helium nuclei. This kind of atomic disintegration is called alpha radio-activity. The lead is the nuclear mass remaining after the explosion of all the supernumerary protons.

In the first attempts at dating, an effort was made to measure the amount of helium contained in radio-active rocks. Although the first results obtained appeared inordinately long, it was noticed that they were systematically too weak, for part of the gas had escaped through the rock.

Instead of measuring the helium, the researchers limited themselves to the lead. The disintegration of uranium produces an isotope of lead, different from ordinary lead. In fact there are three radio-active elements, uranium 238, uranium 235, and
thorium, which give three different isotopes of lead. The method is therefore very effective, for we have three clocks linked together and we can verify the results of one by another.

Shortly before the war another radio-active clock was discovered, which uses the disintegration of rubidium 87 into strontium 87. Rubidium, a silvery metal with the curious property of exploding on contact with water, has the advantage of being much more widespread in nature than uranium. Furthermore, it has a lifespan of $5 \times 10^{10}$ years.

Nevertheless it seems that the most practical method is the use of argon-potassium. Potassium contains, in the proportion of 1 to 8,400, a radio-active isotope, potassium 40, which disintegrates producing calcium 40 and argon 40. Potassium is very convenient since it is found almost everywhere, especially in sedimentary rocks. Besides, its lifespan, $1,310,000,000$ years, gives it a vast range of use.

All these elements have such long periods that they cannot be used for short periods of a few hundred thousand years. The archaeological method of dating by carbon 14 cannot go back beyond fifty thousand years at the very most. So we need a clock for dating from one million to fifty thousand years. This period is extremely important, since it covers the beginnings of human history. It is hoped that this gap can be filled by using beryllium 10, a radio-active isotope formed, just like radiocarbon, by cosmic rays, but with a life-span of two and a half million years. But the beryllium clock is not yet fully developed.

Is it certain that in the course of geological ages radio-active atoms always disintegrated at the same rhythm? If the rhythm varied the whole method would be wrong. Today we possess theoretical and practical proof that it was indeed so.

The German physicist C. von Weizächer has calculated that for the rate of disintegration to vary, atoms would have to be subjected to a pressure of several billion atmospheres and to temperatures of several billion degrees.

Furthermore, the American G. H. Henderson has studied the minuscule brownish halos formed in granite by radio-active atoms emitting alpha particles. He observed that on rocks more than one billion years old these halos formed series of absolutely regular
concentric circles, proving that the emission rhythm of alpha particles has always been constant.

Thus our radio-active clock is working correctly. What time does it show?

From the most recent information our earth is six or seven billion years old. In 1963 the Russian E. Guerling discovered a rock five billion years old in the Baltic. And scholars estimate that we must allow one or two billion years between the earth's birth and the formation of a solid crust.

We do not have a precise and definitive explanation as to how things happened six billion years ago. The time is too remote. If the earth was only a pebble lost in the void the task of specialists would be relatively easy. But our planet constitutes a celestial body of extremely complex composition, and it is also an integral part of a cosmic whole, namely the solar system.

Two basic questions divide cosmologists. Was the solar system engendered by a unique celestial body, or by the combined action of two "parents"? And were the planets formed hot or cold?

The most famous cosmogonic hypothesis, that of Laplace, supposed that the planets were formed hot, at the centre of a whirling stellar mass. A star of very meagre density, but extending to the dimensions of the solar system, the proto-sun would have been concentrated as it turned faster and faster. While the centre was contracting, rings would have formed in its equatorial plane, which would then have condensed into planets. Many problems were resolved by this hypothesis, giving it a century of fame. Then it was noticed that it contradicted a whole series of physical laws.

Laplace's theory was abandoned. Recently, Fred Holye took it up again by supposing that only a part of the matter expelled by the proto-sun had formed the planets, the remainder having been lost in intersidereal space. With this correction, the expulsion of planetary matter by a body in rotation could be admitted.
TWO STARS FOR ONE EARTH

After Laplace's theory was abandoned, scholars envisaged the possibility of interaction between two stars. Suppose that two stars have just brushed past each other. The liquid mass will experience colossal tides. It is conceivable that one of the stars will lose part of its matter, which will then be condensed into a planet. Our earth would be a petrified stellar wave.

Given the extraordinary distance between one star and another, the consequence of this theory to make solar systems an altogether exceptional phenomenon. We would have had to give up the plurality of inhabited worlds and resign ourselves to solitude. Also we would have been forced to concede that our earth was born of a quite extraordinary coincidence of circumstances. But scholars do not like miraculous chances, and so this theory too was more or less abandoned.

Professor Dauvillier has proposed a much more convincing version of it. To him, the solar system was formed at the centre of a galaxy in a region where stellar destiny is incomparably greater than it is in the whorl which we live in now. In such an environment, there is nothing extraordinary in the meeting of two stars. Two stars would come together until a system of double stars is formed. Attracting each other, they would finally fuse, but before that happened their reciprocal actions would have caused them to expel matter. This effect being produced on both stars at once, the proto-planets would be born in pairs, one coming out of each star. The pair of stars, turning at very great speed, will give the twin proto-planets a very high angle of momentum. The expulsions took place in the order observed at the present time, Pluto first and Mercury last. The proto-planets constituted actual little stars having a mass of stellar matter much greater than that which is found in the solar system now. The mass of the terrestrial twins in particular must have been ten times that of the earth.

After the expulsion of the last pair of planets the two stars fused to form our sun. For their part, the proto-planets finally met each other, two by two. By the same process they formed satellites then fused under conditions that varied according to the planets.

In the case of the earth, fusion took place without forming a
satellite. However, its angle of momentum was so high that it ended up by getting out of shape (it was liquid at the time) and expelling the moon. The effects of the consequent tide slowed down the earth, and the moon drifted away. To Professor Dauvillier, Darwin’s theory that the moon was expelled by the earth is acceptable only if one supposes a disequilibrium in the earth’s mass after the fusion of the two proto-earths. Also, being carried out at a time when the earth was still liquid, the operation has left no trace. He therefore rejects absolutely the notion of a “Pacific scar”.

THE SNOWBALL PRINCIPLE

A snowball which rolls over a field of snow gets bigger until it becomes hard to move; all children have tried the experiment at some time or other. Could not their game reproduce also the formation of the earth? We have tried up to now to explain the earth’s birth by the cooling of incandescent stellar matter; may we not suppose, on the contrary, that it was formed by the slow accretion of cosmic dust?

The hypothesis is not new since it was advanced—in a different form, it is true—by the philosopher Kant.

The principle itself is simple: in a cloud of cosmic dust the particles gathered round some nuclei. The process begins cold. But little by little, gravity and radio-activity raise the temperature of the planet as it is forming.

Opinions differ among cosmologists as to the origin of this planetary “primary substance”. To some the sun captured a cloud of cosmic dust. The accretion theories rest above all on the discovery of clouds of cosmic dust and on the abundance of the “rain” of micro-meteorites constantly falling on our earth. Some cosmic clouds can reach several light years in diameter. Their contraction sometimes gives birth to two or three stars. The residual matter can form planetary systems.

Scientific estimates of the quantity of cosmic dust received by the earth keep growing in staggering proportions. The last count advanced is suitably shocking: two and a half billion tons per year. This figure was established in 1963 by a young French researcher,
The Earth is Alive

Tovy Griebe, by observation of the sun, crosschecking the observations made by the artificial satellites, notably the Explorer, which had given ten million tons a day.

The consequences of this discovery are limitless. Each year the earth receives from the cosmos a mass of iron equal to half the world’s metallurgic production. But there is something more important. If the fall of cosmic dust has remained constant since the formation of the earth’s crust, we can estimate that it has deposited on our globe a layer of from twenty to twenty-five feet thick according to the age of the crust. Certainly it is possible that we passed through galactic regions very rich in cosmic substances. At any rate the abundance of cosmic matter is generally considered a strong presumption in favour of accretion.

Some believe the sun itself was formed in the cloud. In the latter case the planets would have been formed before the sun, the thermo-nuclear reaction taking a very long time to release itself in the central nucleus of the primitive cloud.

Scholars clearly have tried to explain in more detail this process of accretion which seems too much like a convenient postulate. Urey thought that snow was the “cement” of the proto-planets. He envisages the possibility of fabulous snowstorms sweeping space over tens and even hundreds of millions of miles. Fred Hoyle thinks that the proto-planets were covered with a kind of bitumen to which the cosmic particles cohered. Magnetic or electrostatic effects have also been considered.

ON THE WAY TO LIFE

Up to now we have been interested only in the formation of a proto-earth, a mass of matter that has little to do with our home, so complex is its structure and so perfectly balanced is its totality. Can a ball of stellar matter or an agglomeration of cosmic dust evolve as far as our earth and mankind?

Without anticipating the following chapters, we can already take for granted that the earth contains at its centre a heavy nucleus, probably composed of iron, surrounded by lighter layers, where silicon is preponderant. A cosmogony which did not include a high temperature phase could end up only with a
homogeneous sphere like the moon, for example. Followers of the "formation by accretion" theory have calculated that the temperature of the proto-earth increased progressively under the double influence of gravity and radio-activity. The whole of its mass would have become sticky, allowing currents of matter to form. Kuiper thinks that the process must have taken about one billion years. The heavy elements then flowed toward the centre. During this time the lighter silicate products came to the surface. In this hypothesis, the proto-earth must never have known a state of total liquefaction. The distribution of the elements was effected in a still very viscous environment and therefore at a very slow pace.

An experimental verification of this process was recently carried out in Moscow. Soviet scientists melted a meteorite (which we may suppose to be fragments of an aborted proto-planet). As the temperature rose gradually, the matter was distributed into successive layers with the heavy metals at the centre, then dunite (a heavy rock with an olivline base probably constituting the basic part of the earth's covering), then a surface layer, basalt. In all probability this is the composition of the globe itself.

At this stage in its formation, our earth still is not suited to supporting life. It lacks its atmosphere and its hydrosphere. Air and water were formed following complex chemical processes, in proportion as the temperature lowered. The primitive atmosphere contained an enormous amount of hydrogen, whether in a free state or in combinations, chiefly of methane (CH₄), ammonia (NH₃), or acetylene (C₂H₂). If we concede a "hot" formation, the gaseous envelope must have reached a temperature of several thousand degrees. Water and carbon dioxide, being dissociable at these temperatures, must have been missing. Most of this poisonous atmosphere (all of it, according to some) escaped into cosmic space. This was notably the case with the rare gases, helium and especially hydrogen, whose compounds became separated in the upper atmosphere.

When the temperature approached 1000° centigrade the water vapour, the carbon dioxide released by the overheated earth, and the nitrogen produced by the decomposition of ammonia, formed
the basis of the atmosphere. Then, on the earth the ocean of melted silicates began to solidify while an intense volcanic activity continued to release enormous amounts of water vapour and carbon dioxide. The atmospheric pressure exceeded 200 atmospheres and the enormous electrical charge of this gaseous mass caused storms of unbelievable violence, unlike anything known in our time.

This atmosphere must have contained no oxygen in a free state. A study of the products of volcanoes today leads us to believe that the exhalations of the juvenile earth did not contain any. The only source of oxygen therefore was the decomposition of molecules of water. It is ultraviolet radiation which separates molecules of water. Oxygen seems to remain in the atmosphere, while hydrogen disappears in the earth’s “halo”, thousands of miles away.

But oxygen is anything but solitary; it always finds a body to combine with so that it does not remain free for long. The quantity of oxygen fixed in the earth’s crust is from three to six times greater than that in the atmosphere. Given this passion always to combine, there is every reason for thinking that the primitive gaseous envelope contained only traces of it in a free state.

When the temperature fell below 100° centigrade the oceans began to form. It would seem that the hydrosphere has a double origin. On the one hand a geologic deluge would have discharged the atmosphere of its water vapour and carbon dioxide; on the other, great quantities of water would have been disgorged by the molten rock. The second process has continued throughout the history of the earth and today most of the earth’s water is kept in the globe in the form of hypercritical water, i.e. at more than 370° centigrade under great pressure. Part of this water continually rises to the surface. It has been given the fine name of “juvenile” water.

**LIFE APPEARS**

Now all is ready for the great miracle of life. This declaration may come as a surprise. Were we not left with an unbreathable atmosphere made of carbon dioxide, water, nitrogen, methane, and
ammonia? Here is the perfect toxic gas for asphyxiating all species of life. Should we not consider that the atmosphere was freed of toxic bodies and enriched in oxygen before the appearance of life?

This idea, which held sway for a long time, rests on a false view of the world, life, and man. In this perspective, life would have appeared independent of its environment when its environment was definitely ready to receive it. The Bible tells us that God first created the earth; then he put man on it.

In the light of the most recent discoveries, life appears not as an artificial addition grafted onto geological reality, but as its necessary continuation. For the scientist of today, the miracle is not that life appeared on earth; the miracle would have occurred if life had not.

This impression results first from the great experiments made on the synthesis of life, notably Stanley Miller's. When he was only a student of Urey's at Columbia University, Miller had the audacity to try to recreate what had happened at the dawn of geological times. He enclosed in a sealed environment a gaseous mixture corresponding to what the primitive earth's atmosphere must have been (ammonia, hydrogen, water, and methane), and for several days he subjected it to violent electrical discharges. At the end of this experiment he ascertained the formation of a great number of complex organic compounds, amino acids in particular. In 1963 Doctor Cyril Ponnamperuma subjected a similar mixture to electronic bombardment and manufactured an organic compound of the most complex kind, adenine. Finally in 1964, the Americans Fox and Harada formed amino acids by merely subjecting the famous mixture to intense heat.

At the same time as we were discovering the possibility of a natural synthesis of complex organic compounds on the primitive earth, the scale of life's manifestations was being revealed as infinitely more extensive than was supposed. Bacteria were found absolutely everywhere, in springs of boiling water, at an altitude of fifty thousand feet, at the heart of atomic piles, where radiation would kill evolved beings in a few moments. We know that there exist a great number of anaerobe bacteria which do not require oxygen to thrive and which, as they decompose organic matter,
can release oxygen in an environment which contains none in a free state.

As we face these two observations and add the time factor (the hundreds of millions of years which make accidents inevitable) we feel very close to the great miracle.

Most likely life appeared in the form of the most elementary biological manifestations in a world incapable of supporting higher organisms. This birth of birth made no external intervention necessary; it simply needed millions of years to have its opportunity to happen. But this first vital spark carried inside it irresistible dynamics which made it evolve toward superior forms of organization. Parallel to this organic evolution, a geologic evolution was taking place, preparing the earth for the appearance of more complex being. Life played a big role in this transformation of the earth; in particular, it released oxygen.

In fact it is chlorophyllian assimilation that supplies oxygen; if it stopped, the atmosphere would finally contain only nitrogen and carbon dioxide. But life is not content with periodically renewing oxygen; it has without any doubt built up, bit by bit, the necessary stock for the respiration of the animal kingdom.

Life therefore appeared on a particularly hostile earth, and as it developed it modified nature and prepared it progressively to receive more perfected organisms. Otherwise stated, it is not by accident that the earth responds to the very strict demands of higher beings, nor does it do so by some miraculous intervention; it is simply that it has supported life for a very long time. Schematically, one can say that our planet is habitable only because people inhabit it or because evolution has adapted us to the terrestrial environment and has adapted that environment to our needs.
The Shape and Size of the Earth

When we said at the beginning of this work that scholars knew nothing about gravitation, we meant of course that they were in the dark about its nature, for its effects are known with all the accuracy we could wish. This force is exerted according to the same laws as magnetic and electric forces: proportionately to the square of the distances.

But it is incredibly feeble. The force of gravity is $10^{99}$ times weaker than the force of nuclear cohesion. That is the relationship that exists between one ten-millionth of a gram and the sun’s mass.

The works of Dirac have shown that the emission of gravitational waves occurs by successive units or quanta, just as for light. For light the quanta is called a photon. For gravitational waves it has been called the graviton; but the fact remains that it has still to be discovered.

For years there has been a price on its head (the reward, the Newton prize, still awaits its laureate), organizations have been

1 P. A. M. Dirac, a British physicist and Nobel Prize winner for Physics in 1933, was the first to proclaim the existence of anti-matter solely from theoretical studies. The discovery of anti-particles confirmed mathematical research in a spectacular way. Evoking Schrodinger’s scruples in publishing his equations—at this time electron-spin had not yet been discovered, and consequently Achrodinger’s equation had been only approximately confirmed by experiment—he wrote: “I think that there is a moral to this story, namely that it is more important to attain beauty in one’s equation than to see that it correspond to experimentation.”

This extraordinary audacity in theoretic research led Dirac to launch out into the study of gravitation. His work made physics leap forward, by giving a theoretic base to the gravitational wave as well as to the quanta of gravitational forces. Although his work is little known to the public at large, being too difficult to follow, Dirac is one of the greatest of contemporary thinkers.
specially created in order to find it (the European centre for research in gravitation, for example), but it stays out of our grasp.

Today we wonder if the graviton was not a false identity, the real one being simply the neutrino. This particle, practically unmaterial, the existence of which was postulated by Pauli some thirty years before its discovery, possesses the incredible power of travelling through all masses and all screens. Every second, each square centimetre of the earth's surface is crossed by dozens of billions of neutrinos emitted by the sun. Linked to these particles are anti-neutrinos, the only particles of anti-matter that reach the earth.

All this must seem to have only a very distant relation to the earth. The interest which geophysicists bring to studies on gravity will be sufficient to prove the contrary.

In an Einsteinian view, the intensity of gravity must remain constant. But there are many scholars today who are sceptical. Unfortunately their researches lead them to diametrically opposite results. To some, we are increasingly light, and to others increasingly heavy. In both hypotheses these variations clearly remain infinitely slow, and there is no danger of their influencing the performance of high jumpers. Though inoperative on the scale of human history, this phenomenon could none the less have enormous consequences for the past and future of our planet over billions of years.

First of all let us see what the scholars say who make us lighter. Dirac reckons that the surprising weakness of gravitational forces is explained by their constant diminution in relation to the expansion of the universe. Developing these views, R. H. Dicke, of Princeton University, calculated that the diminution of the gravitational constant must involve an expansion of the globe. In three and one-half billion years its radius would thus have been lengthened more than 5.5 per cent. The faults recently discovered beneath the oceans would have been caused by this expansion of the earth. Taking up this hypothesis the Soviet scientists Ivanankov and Saguitog have estimated the lengthening of the earth's radius at 2.68 inches per century.

On the other hand the Russian scholar V. D. Neimann estimates that the intensity of gravity has not stopped growing. This growth goes on at an extremely rapid rate since, according to him, it was
ten times weaker during the Cretaceous Period (a hundred million years ago). Should we not deduce that the globe is forever contracting?

Neimann thinks exactly the opposite. Since that epoch, he has calculated, the acquisition of cosmic matter has increased the terrestrial diameter by 2.6 times. In the Cretaceous Period, the earth was entirely covered over with a solid crust and had no hydrosphere. The continents and oceans in that case would have been formed in the course of the last hundred million years.

Clearly here are visions that seem to belong in the first chapters of this work; and indeed Soviet scientists have not failed to cry "science fiction"! Dicke’s ideas are considered extremely controversial in the United States also.

To find the truth, scientists are counting on the advance of nuclear physics and on the utilization of artificial satellites. In the latter sphere, Professor Dicke has proposed an experiment which could settle the question, namely, to launch a satellite that will perform the functions of a pendulum. Its behaviour over a long period will be compared to that of an atomic clock functioning according to the movements of the electrons in atoms, and therefore independently of gravity. Professor Dicke estimated that thanks to this experiment we could know in five years whether the gravitational constant really deserves its name.

FROM GRAVITY TO WEIGHT

Even though the force of gravity is very weak, when the "gravific generator" reaches the size of our globe, its intensity takes on sizeable proportions. Why is this terrestrial field of gravity always referred to as weight? For the two terms to be synonymous, our globe would have to be motionless and perfectly spherical. Its rotation causes a centrifugal force which opposes the centripetal attraction of gravity. Thus this weight, which keeps us on the surface of the earth, is only the component of these two forces. But the speed of rotation varies with latitude, being non-existent at the poles. Centrifugal force being proportional to speed, weight is more considerable in the polar regions than at the equator.
Moreover, the force of gravity at each point on the earth’s surface depends on the distance to the centre. The polar radius being 13.5 miles shorter than the equatorial radius, we have here a second cause for variation in weight according to latitudes.

For example, something that weighs 1,000 kilograms at the pole weighs no more than 995 kilos at Brazzaville. To take again the example of the high jumper, it is certain that here the difference, however tiny, would be calculable. There would be a difference of about a half inch between the jumper in Archangel and the jumper in Belem. Will we have to introduce a “latitude correction” into athletics records?

Without waiting to lay hands on the elusive graviton, scientists have started a systematic sounding of the earth’s field of gravity, which has told them about the exact form and secret structures of the earth.

If the earth consented to accept the biblical flatness which Voliva bestowed on it, the task of scientists who wished to draw it would be extremely simple. Unluckily our earth is not a pancake, nor a revolving sphere; it has a shape all its own, halfway between a pear and a potato.

Those swellings which deform our planet are in no danger of being noticed by one travelling over its surface. They are minute in proportion to the size of the planet. If our globe were reduced to the proportions of a billiard ball, nothing would betray these irregularities.

THE NAKED PLANET

Before outlining in detail the irregularities of this globe, it would be wise to deal rather precisely with a seemingly simple problem: drawing the earth.

The problem is two-fold. First, it is necessary to make a minute study of the variations on the earth’s surface: mountains, rivers, valleys, etc. This first task belongs to geodesists. The method they use, called triangulation, consists of carefully measuring a base and aiming at a point from its extremities by elevating the angles which these directions form with the base line. Thus we obtain a triangle, of which the base and the two adjacent angles are known;
the calculation of the other sides becomes a problem of elementary
trigonometry. The determination of the altitude is made normally
by successive sights on surveyor’s poles, which are graded and
vertical. That is the first job of “earth-drawers”. But once they
have obtained a faithful reproduction of the variations on the
earth’s surface, they must carry over their results to the body of
references dealing with the exact shape of the globe. We could say
that it is necessary to undress the earth in order to know its forms,
to draw its clothes exactly, and then to reassemble the whole.
Only then will we have obtained an exact picture of our planet.
It is quite surprising to think that we are only just succeeding to
get this picture.

We were still very far from a perfect picture at the dawn of the
International Geophysical Year. The very shape of the globe was
known only as a first approximation, its dimensions being
estimated to within tens of yards. As for the drawing of the
surface, it looked like an ill-fitting puzzle.

On the continents, as the result of a colossal process of triangula-
tion, a figure precise to one-ten-millionth was reached. Unfor-
tunately, the fixed bases necessary for the work of triangulation
could not be found in the oceans. They represent two-thirds of
the earth’s surface.

Consequently, we knew the position of certain islands in the
Pacific only to within several miles. For an area as important as the
Bermudas the margin of error exceeded 300 feet, while the width
of the Atlantic was estimated to within six-tenths of a mile.

In these circumstances the facts could not answer such essential
questions as: Does the earth expand? Do the continents move? Do
the mountains rise?

Thus the second task of the geodesists consists of undressing
the globe and eliminating all relief. Where to find this naked
earth? It seemed clear that it could be found on the oceans.

The reasoning was as follows: determine the form that the
surface of the seas would have if continued in place of the
continents, and you will have unclothed the earth.

The problem of how to determine this ocean surface (where there
were no oceans) could be solved by making a study of weight.
The surface equilibrium in water has the twofold theoretical
characteristic that weight must be the same at all its points, and that it is perpendicular to the direction of a plumb line. Now, we know that weight diminishes regularly with altitude. So the problem seems simple enough. We know the intensity of weight at sea level. We know its rate of diminution with altitude. We also know that the surface to be laid bare is perpendicular to the direction of the plumb line. We have only to mark this direction at each point and calculate the intensity of weight to be able to determine the form of the naked earth. All that remains is to lay on the variations in relief.

Polar flatness should give this stripped earth the surface obtained by turning an ellipse about its diameter—a revolving ellipsoid. Though not easy, it is possible to calculate this theoretical shape. If you then wish to prove by measuring the weight that this really is the shape of the unclothed earth—which from now on we shall refer to by its horrible scholarly name: geoid—we generally find that the facts do not correspond with the theoretical calculation. The plumb line is not perpendicular to the imaginary surface, the ellipsoid, but to one considerably different, the geoid, or—it comes to the same thing—the intensity of weight corresponding to the level of the seas is not exactly reached at the surface of the ellipsoid, but above or below it. "Weight anomalies" occur.

That is, compared to the regular and geometric surface of the ellipsoid, the geoid undulates above and below the average.

Geoid is defined as a surface of equal weight. How can a surface of equal weight have the deformed shape of a potato? Theory shows that, if this is so, it is because the distribution of masses in the interior of the globe is not regular. Suppose a very heavy body, iron for example, is buried two miles below the surface: this surplus of mass will be expressed by an abnormally high weight.

The geoid is a purely intellectual concept, an abstraction; it has no geographical reality. So we cannot compare it with the nucleus, for example, which is physical fact. It is only a basis for theoretical work. Since the true shape of the earth, the geoid, is irregular, how do we determine it exactly? Artificial satellites finally gave us the practical method.

The inaccuracy of the first American space shots gave Vanguard I
a very elliptical and distant orbit (apogee: 4,061; perigee: 405). In effect, no more than a radio transmitter, the satellite revolved in space above the atmosphere, and its movement was not slowed down by an friction. Vanguard was obeying only the laws of celestial mechanics, and its orbit depended only on the earth's gravitational field. If the earth had been a perfect and homogeneous sphere, the satellite would have followed a regular course. Subjected to the gravitational field of the geoid, it showed it had just as fickle a disposition as weight on the surface of the earth. The malformations of the geoid were expressed by an orbit different from that calculated for a spherical and homogeneous attracting mass. In its celestial course, Vanguard irreverently mimicked the irregularities of our bumpy earth. From the disturbances of the satellite it was possible to deduce by calculation the exact shape of the earth. To obtain sufficiently exact results, the Americans had to focus an amazingly accurate observation system, the minitrack network, which made it possible to determine the satellite's position to within twenty-six feet, an extraordinary result considering they had to place in position a grapefruit-sized object, travelling at five miles per second at a distance of several hundred miles. This accuracy finally made it possible to obtain the exact dimensions of the globe. The margin of error could be reduced to about 32.5 feet. According to Vanguard the equatorial radius measures 3,960.88 miles, 13,274 miles more than the polar radius, which gives a flattening of 1/298.37. This result is a brilliant testimony to the validity of the work of the Soviet geodesist, Krassovsky. During the war he gave 1/298.3 as the terrestrial flattening.

Thus measured, the earth will soon be forced to reveal whether it is growing fatter or thinner.

Vanguard revealed something still more spectacular; that our globe is shaped like an egg. This was deduced by Ann Eckels and Dr. J. A. O'Keefe from irregularities in Vanguard 1's orbit. The calculations developed from these observations show that the planet is slightly flattened and convex in the southern hemisphere, while it is thinner and tapers to a point in the northern hemisphere. Because of this the North Pole is 40 feet above the theoretical
ellipsoid and the South Pole is the same distance below it. This deformation affects the harmony of the polar regions. In the southern regions the swelling makes the sea level exceed its theoretical point by 38 feet. At the other end of the planet, by contrast, terminal narrowing reduces it 26 feet below normal. These contrary anomalies decrease with latitude.

Scholars are not too sure how to interpret this pear-shaped configuration. To some, it proves the rigidity of the globe, to others, its plasticity. Since then it has been noticed that, even for a pear, the geoid was less than perfect. The observations of "Transit IV A" in 1961 showed that the equator was not the perfect circle it was thought to be. In actual fact it appears to be an ellipse, with the semi-axes differing by 500 feet.

It would be a grave error to think that the use of geodesic satellites has made the traditional methods of gravimetry useless. Satellites help in studying the globe as a whole, but for local measurements the classic techniques remain the only effective ones.

There are two ways of measuring the intensity of weight. The first is to measure the traction exercised on a spring by a mass. If the weight increases the mass weighs more, the traction of the spring increases, and the spring lengthens.

The second method is to measure the oscillation time of a pendulum. It is known that this period depends on the mass in balance. A change in weight is expressed in a change in the period of the pendulum.

These techniques have reached such a degree of perfection that today simply by measuring weight one can see whether there is an underground cavity or if the mass of excavated earth weighs generally more than the materials embodied in the construction of a building. The most spectacular application of the technique is clearly in mining and oil prospecting.

From what we have said up to now, gravimetry could be considered a rather easy science. Doesn't it involve only the ability to read off the intensity of weight on a gravimeter? Besides the fact that this operation is much more delicate than it seems and is not at all like glancing at one's watch to see the time, it constitutes only the preliminary to gravimetric measurement. The weight measured on the gravimeter tells us about the earth
with its clothes on, and geodesists are still trying to determine the
shape of the naked earth, the geoid.

In order to pass from earth to geoid, scientists make, from
observed measurements, a whole series of very complex calcula-
tions called reductions.

First, it is necessary to make allowance for altitude, which
diminishes weight. But the mass of ground which is piled up
between sea level and the level on which observation is carried
out, exerts attraction. The scientists will deduct the gravity
Corresponding to this mass, which in our metaphor is the weight
of the earth's clothes. Still other corrections will make allowances
for luni-solar attraction, that of external masses (e.g. if the
measurements are taken at the foot of a mountain); in short, the
geodesist must work with the figures read off on his gravimeter
for a very long time before being able to interpret them.

When the first gravimeter measurements were taken in 1740 by
Bouguer in the Andes, he established that the value of weight at the
top of a mountain was less than in a plain, even allowing for the
diminution corresponding to altitude. Everything happened as if
the huge mass of the mountains exerted no gravitational pull, as
though the mountains' mass weighed nothing. At one time it was
actually believed that mountains were hollow. Only gigantic
caverns inside the mountains could explain this astounding
deficiency in mass.

We know today that it is nothing of the kind. Mountains are
indeed full, but their weight does not suggest this. Their enor-
mous volume is only a deceptive appearance. To understand this
phenomenon we shall anticipate the following chapter a little.

Schematically, we can represent the earth's crust as a solidified
cover of a heavy material, basalt, in which are congealed contin-
nental blocks made of a lighter rock, granite. Beneath this rigid
crust lies a rocky paste of great density: magma.

Therefore, one can lay down the following as primary geo-
logical laws:
— the ocean beds are basalt and the continents are granite;
— basalt is heavier than granite;
— beneath the crust there is a rocky paste: magma.

We therefore have a solid mass laid on a plastic bed. Between
the two layers a phenomenon of floating will occur, a floating between two solids in a way, but we shall see that over a long period of time magma, although very rigid, can behave like a fluid.

The law of flotation of bodies requires that the fluid support an equal mass at every point, that there be a hydrostatic equilibrium. A simple example will illustrate the phenomenon. When an iceberg floats on the ocean, most of its mass is submerged. Thus a certain volume of water is replaced by ice. Since ice is lighter than water, a deficiency of mass occurs, which counterbalances the excess constituted by the submerged mass of the iceberg.

It is the same for the earth’s crust. Roots of light granite develop beneath mountains, which take the place of the heavy magma. In this way, the hydrostatic equilibrium is re-established. This state of hydrostatic equilibrium between the earth’s crust and the magma is called isotasis.

As the earth is not a rigid, motionless body, but a mass constantly performing evolutions, isotasis is not a state of equilibrium acquired once and for all, but a constant pursuit of a state of equilibrium which is impossible to maintain.

The earth is forever being modified; mountains appear while others are destroyed by erosion and are met with again at the bottom of the oceans. The terrestrial crust becomes hollow and rises. As we shall see, the same dynamism exists in the interior of the globe.

These displacements of mass continually disturb the hydrostatic equilibrium. But the earth does not tolerate disequilibrium: it works unremittingly to counterbalance it. If a mountain forms, it will develop granite roots, according to processes that remain mysterious. In proportion as they are eroded, it will raise these roots to maintain this balance. Consequently, if some gigantic bulldozer suddenly demolished the Alps, another mountain would soon rise, created by the rising of the deep roots.

Another particularly spectacular example of this isostatic dynamism can be observed in Scandinavia. In the Quaternary Period, these regions were crushed by a huge glacial mound. This overload made the crust subside. After the break-up of the ice, an opposite phenomenon raised up the Scandinavian plateau. But this
phenomenon is much slower than was the rate of melting, and at the present time Scandinavia continues to rise at the rate of three feet per century.

How will this state of hydrostatic disequilibrium appear? Precisely in anomalies of weight. When these anomalies are slight and distributed over a very large surface, the counterbalancing work of the earth is imperceptible. It is established that the ocean basins generally have too much weight because of their very heavy basalt carpet, but there is no perceptible movement in the planet to compensate for this. On the other hand, there are regions where very considerable anomalies are found, on relatively weak surfaces. In these zones the earth sets to work establishing a normal situation. In a general way, therefore, the earth’s crust is in full transformation in regions with great anomalies of weight; these are the active zones of the planet.

This terrestrial dynamism is not peculiar to isostasis. In every sphere we discover the ceaseless struggle put up by the earth for billions of years to counterbalance ever-reappearing distortions. This quest for an unattainable equilibrium is simply the principle of all action and all dynamism. Because our planet can neither find its equilibrium nor tolerate disequilibrium, it is a dynamic body which works and will work for eternity.
14/ Life in the Inner Depths

To scholars of the 1960’s, the earth to be explored is very different from that of the first geologists. To them the terrestrial globe was essentially a sluggish, passive mass whose fate was to submit. It submitted to erosion which levelled its surface, to cooling which wrinkled its surface, etc. . . . It was a decrepit world which was little by little catching its death of a cold. “We are witnessing the collapse of the globe,” wrote Suess.

Today, geophysical dissertations speak of the life of the globe, of profound dynamism, and of physiology. The earth is compared to an atomic pile, a dynamo, a chemical factory, etc. . . . It seems a thoroughly active organism. But there is no question of returning to Dr. Jaworsky’s geon. When we say “organism”, we are not thinking of the biological sense of the term, but more generally of “a structure prepared for functioning”.

Our earth does function. Deep in its bowels are born thermic, radioactive, magnetic, and mechanical forces which do their work in a veritable bath of energy supplied by the sun. The working of these forces maintains a dynamism made up of cycles, exchanges, re-adjustments, transformations: a “physiology”, as professor Tuzo Wilson calls it.1 Dynamism implies a consummate unity in the earth’s structure. Action is the greatest force which can cement a structure. Inert masses are always merely juxtaposed, and their unity could only originate from indifferentiation.

Thus all the elements of the terrestrial mechanism are as closely linked as the organs of a living being. Consequently, by isolating phenomena in order to study them more easily, we are arbitrarily

1 As President of the International Union of Geodesy and Geophysics during the International Geophysical Year, Professor J. Tuzo Wilson is one of the scholars who has done a great deal to make recent advances in earth science known to the Anglo-Saxon public.
mutilating reality. There is no other way to proceed, but we must be aware of the artificial character of this process of "cutting up".

We know now that the earth is a dynamic organism, comprising the terrestrial globe, the hydrosphere, the atmosphere, and the biosphere in a single unity. Unfortunately, we know very little about the innermost life of the earth-organism. Here we are walking on the shifting sands of hypothesis. But these hypotheses do give us a vague picture of the earth which will be discovered in the future. "The speculations of today will guide the knowledge of tomorrow," wrote the American geophysicist Daly. Today the earth is still to be unveiled.

In the monumental work, *The Earth* (Encyclopédie de la Pléiade, 1959), published under his direction, Professor J. Goguel brings to the fore innumerable unanswered questions concerning the functioning of the earth-machine. He writes: "All these questions are just beginning to be asked. They are by no means resolved and cannot be all at once. We shall have to risk many more hypotheses, some of which will seem daring but which will contain perhaps a particle of truth, and many inadequate diagrams concerning only some of the elements in view, before a synthesis, however improbable, can be attempted. . . . For the present, if we begin to have a fair knowledge of some of the surface repercussions of this inner life [of the globe], we still barely have a presentiment of the direction in which an explanation should be sought."

Such is the state of the earth sciences as defined by one of the greatest French specialists. It is a case of presentiments based on an accumulation of hypotheses. Most of the theories postulated about the earth should therefore be studied as conditional.

**FORBIDDEN TO MAN**

Nothing could be more superficial than our knowledge of the earth. We have the right to walk on its surface, but its inner parts are forever and ever forbidden us.

The *Journey to the Centre of the Earth* dreamed up by Jules Verne is limited to the exploration of abysses of which the maximal depth hardly exceeds 3,000 feet.

Natural apertures end rapidly in dead ends; from there on we
must dig. In this field the record is held by the miners who extract gold ore at the bottom of Robinson Deep in South Africa. At these levels, only very powerful ventilation devices can maintain conditions at the extreme limit of human tolerance. How close have these men, suffocating in the heat and unbreathable air, approached to the heart of the earth? They are 1.86 miles from the surface, while the centre is still over 4,000 miles beneath their feet.

So the road to the centre of the earth seems to be irremediably cut off from men. Can they get a little closer?

An initial technique might be to dig wells without man’s having to go down in them. The deepest drillings made by the oil industry barely exceed five miles.

The American Project Mohole has received a great deal of publicity. Since the earth’s crust is thinner under the ocean than under continents, the Americans decided to drill under the sea. The idea is simple, but it raises very difficult technical problems which still have not been resolved. The main one is that of making sure that the drilling rig is vertical to the shaft. A firm anchorage is impossible since the drilling must be done at the bottom of very deep trenches; so it was decided to equip the ship with four outboard motors, which would enable the ship to rectify its position at any time. The problem then was to be able to know the ship’s bearing at all times with absolute precision in order to make the necessary corrections. To do this, three submarine radar buoys and four submarine sonar bouys were placed around the ship. A sonar system was installed under the hull. It turns on itself, constantly emitting a signal which the buoys send back to it. An automatic calculation system makes it possible to rectify the ship’s position immediately if the signals received show that it has drifted.

To reach their objectives the drillers must overcome many other equally difficult problems. The cost of the experiment will come to a fortune (at least 50 million dollars). The drilling head, made by a French company, is equipped with 2,500 diamonds (approximate value $8,000).

The first attempts were carried out in 1961 off Guadaloupe. The decisive boring will be done at the bottom of the sea off Puerto Rico.

The Russians did not want to risk sea drillings and decided to
dig on firm ground. They plan six deep drillings in their territory. One to be made in the depression of the Caspian will be about ten miles deep. Its basic objective will be to study the structure of the terrestrial crust in sedimentary basins.

Wells planned for Karelia and the Kola peninsula will help in studying the composition of very ancient granite formations. A drilling will also be made in the Urals through terrain very rich in mining deposits, while the Azerbaijan drillings will cut through both the granite stratum and the underlying basalt. Finally in the part of the Kurile Islands where the crust is very thin, the drilling will pass through the moho and will penetrate the mantle as far as possible.

We can see that for the Russians it is not a case of bringing off a technical feat—they have already passed the four-mile mark in Kazakstan—but rather of systematically prospecting the earth’s crust. Their plan is much more comprehensive than project Mohole.

Yet the dream of a human journey into the bowels of the earth is not abandoned. Professor Lavrentiev of the Russian Academy of Sciences has lately presented a plan for an autonomous and habitable machine capable of going 60 miles deep. It is a kind of gigantic underground rocket. The drilling head would be a nuclear reactor which would release sufficient heat to melt the substances that make up the earth’s crust. The device would penetrate the earth like hot metal in wax. It could tolerate temperatures of 1,000°C centigrade and pressures of 30,000 atmospheres. Obviously it is a distant project of which the realization is hypothetical, but it indicates man’s deepest possible penetration in the foreseeable future. Even if this fabulous scheme worked, we would hardly have travelled more than a tenth of the earth’s radius.

Indirect means of observation remain the surest way to gain access to the inner secrets of our planet. The American physicist Adams has proposed a method considerably different from Lavrentiev’s system. It involves a kind of needle with a tungsten head which would be heated by a nuclear reactor. After the instrument is placed at the bottom of a well, we would simply wait for the start of a nuclear reaction. Soon the instrument will
reach a temperature of more than 1,000° centigrade and will begin to pierce the rock, which will melt on contact. At a depth of twenty miles the head of the needle will be detached while the other part, made of light metals, will be brought back up to the surface with samples from the depths. This scheme seems much easier to carry out than Lavrentiev’s.

THE WAVES TESTIFY

On the morning of November 1, 1775, all the churches of Europe were overflowing with the faithful who had come to attend the All Saints Day service. Suddenly spectators saw that the lighted chandeliers hanging from ceilings were swinging gently to and fro. After a time everything went back to normal. Many of the faithful noticed nothing, and no one realized the terrible news which the dancing lights in the sanctuaries were bringing: Lisbon was no more. The capital of Portugal, ravaged by a frightful earthquake, was only a mass of ruins covering thousands of dead.

The extraordinary chance of the catastrophe’s coinciding with the religious service brought it to scientists’ attention that, following an earth tremor, the globe is traversed by waves.

The abrupt energy release of an earthquake produces different kinds of waves crossing the globe in all directions. After strong tremors they can be recorded at numerous points on the earth’s surface. By good luck it is possible to find out from these waves what they saw during their subterranean journey. Scholars can therefore make a thorough radiographic investigation of the earth, thanks to the seismograph.

The seismograph consists essentially of a considerable mass (up to 20 tons) in equilibrium, to which a marker is fixed. Modern versions of this are extraordinary sensitive. One of the most recent seismographs constructed in Paris can record a man’s footstep six-tenths of a mile away. It is true that at this stage of sensitivity the seismograph loses its usefulness since it never stops vibrating from the incessant quivering of the planet. This microseismic agitation is caused by the movements of the ocean and the atmosphere. The masses of the atmosphere and the hydrosphere weigh down upon the earth’s crust and compress it. When disturbances
occur, this pressure varies and the earth’s crust is either pushed
down or relaxes like a spring. These slight movements of the crust
produce innumerable vibrations. L. Don Leet, an American, calls
it “the song of the earth”.

Since seismic waves vanish faster than the disturbances causing
them, the study of microseisms has been used profitably to detect
typhoons originating at sea. A seismograph can pick them up on
the shore before they arrive.¹

When an earthquake occurs, the seismic waves are recorded on
a seismogram: a long strip of black paper traversed by a con-
tinuous sinuating white line. To decipher its meaning, it is neces-
sary to know the seismic waves.

Although there are really three kinds of seismic waves, we shall
deal here with only two, even though the third kind, L (long)
waves, is actually the most important since they move along the
surface and cause destruction. They are disregarded here because,
due to the fact that they travel on the surface, they cannot be used
to investigate the globe. The two that concern us are longitudinal
waves and transversal waves. In the former, the molecules are
compressed tighter and tighter in the direction of the diffusion of
vibrations. Sound waves are like this.

On the other hand, the initial vibration can be transmitted by
downward oscillations. All you have to do to produce a transversal
wave is tie the end of a string to something, hold the other end
without stretching it, then swing your hand downward. The string
then begins to undulate: it is crossed by transversal (or distortion)
waves. Light travels in this way.

The speed of the spreading of longitudinal waves is two-thirds
greater than that of transversal waves. They obviously arrive first
and are traditionally called P (primary) waves, while the others
are S (secondary) waves.

¹ All these technical feats should not hide the fact that seismology seems
to have almost reached its maximum potential. To take its place, some are
already thinking of radiography, using neutrinos. An artificial satellite could
act as a camera, sending a flow of neutrinos on to the earth. These particles
would cross the earth, and at the antipodes a receiver would try to deduce from
their behaviour the nature of the matter which they had crossed. At present the
project is running up against theoretical impossibilities.
The speed of the diffusion of these waves varies with the physical properties of the environments crossed. The more rigid the matter, the faster the vibration spreads. Furthermore, waves are constantly refracted as they change environment. If the change is abrupt, a second wave will be produced: a reflected wave. Note too that S waves cannot pass through liquids.

By using the properties of seismic waves, it is possible to guess the physical nature of the different environments through which they travel.

Seismologists’ research reveals that the earth is not a homogeneous body, but actually consists of several concentrically superimposed layers. To the scientists sounding the planet, passage from one layer to another is expressed in an abrupt change of the speed and direction of waves; also, reflected waves are produced at this level. The wave is said to have passed through a surface of discontinuity, having moved from one zone to another.

Three main zones have been recognized: the crust, the mantle, and the inner core, allowing comparison with a soft-boiled egg; the shell being the crust, the white the mantle, and the yolk the inner core.

The first surface of discontinuity separates the crust from the mantle. It was brought to light in 1909 by the Yugoslavian seismologist, Mohorovicic, and was baptized the “Mohorovicic Discontinuity” in his honour. It is usually called the “moho”. One of the most curious characteristics of the moho is that it does not have an even surface; instead it is in inverse relief to the exterior of the earth. It descends to about forty miles beneath the mountains rising to a few miles under the oceans. Its twisted conformation is obviously in keeping with the mechanisms of isostatic compensation. But is it not certain whether the moho represents the surface of compensation supporting an equal mass at all points.

Passing through the moho, we reach the mantle, the kingdom of magma, which is a rocky paste nearly 2,000 miles thick.

Scholars have come to the conclusion that magma is a plastic body with the rigidity of steel. “A liquid that breaks and a solid that flows”, Prof. Gamow calls it. Paradoxically, these two properties are not incompatible in a single body.
Sealing wax, for example, can be a solid or a liquid according to existing circumstances. If you tap a stick of it with a hammer, it breaks into a thousand pieces; it has reacted as a solid. On the other hand, if it is left in a container for a very long time, it takes the shape of the container, just like a liquid.

Magma has the same properties. Subjected to sudden violent force, it breaks like a solid. These breaks cause trembling on the surface of the earth. On the other hand, under the influence of a force much weaker but applied with geological persistence (and we know that our earth has inexhaustible reserves of patience to attain its ends), it will flow like a liquid. It is this property which permits isostatic readjustments.

Why do rocks become magma in the mantle? In the interior of the earth, matter is subjected to temperatures and pressures proportional to its depth. Now heat and pressure have opposite effects. The former tends to melt substances, while the latter hinders this fusion. The more a rock is compressed, the higher its fusion point. There is therefore a kind of constant movement back and forth between these two opposing phenomena.

It seems that temperature rise is the determining phenomenon in the surface layers. On the other hand, in the deep layers of the mantle the heating of rocks must be much slower, and pressure determines the state of matter. Thus, in the higher levels of the mantle, the rocks are very near their fusion point and consequently very plastic. At greater depths, the pressure raises the temperature of fusion to a point such that the matter, though hotter, is less plastic. The rocks are therefore solid when they are above their fusion point in free air. If magma goes up the funnel of a volcano, the diminution in pressure will allow it to become liquid, even though it gets colder. It is obviously hard to imagine, but magma melts as it cools, if the pressure diminishes.

Magma is piled up, then, up to 1,800 miles in depth. At the lower limit of the mantle the density reaches 5.7 in relation to water and the rigidity is four times higher than that of steel. Abruptly the matter seems to become fluid; we have reached the core.

Suppose a violent earthquake occurred at the South Pole. Almost all over the world seismographs will start to vibrate.
However, those in the United States will remain perfectly still. We say that the United States—and more generally all countries between the latitudes of Dakar and Brussels—are in the “shadow-zone”. For each earthquake there is a zone in the shape of a crown which circles the earth and in which no seismic wave is registered. Beyond the crown the waves reappear. In our example, Sweden would record the earthquake perfectly, although it is farther from the epicentre than is the United States. Beno Gutenberg was the first (in 1914) to give the correct explanation of this phenomenon: at the centre of the earth there is a core which refracts waves violently, giving them a very strong curvature, and making them avoid this shadow-zone.

Since that time, a Danish seismologist, Irene Lehmann, has discovered that the exterior part of the core lets P waves pass, but stops S waves. Therefore, the conclusion must be that the exterior of the core is liquid, surrounding a solid central “seed” of a radius of about 850 miles.

We said “liquid”, but to be rigorously scientific we should only say “having certain properties of a liquid”.

It is difficult to imagine a liquid mass at the centre of the earth. But in addition, if the rigidity collapses abruptly at the extremity of the core, the density, on the contrary, rises rapidly to 9.4. Geophysicists do not know to what these changes correspond. “Something” happens at the extremity of the core, but we do not know what.

Here science is faced with the mystery of high pressures. We have succeeded in reproducing very high temperatures, and theory also shows faithfully enough what happens to bodies which are raised very high temperatures. On the other hand, we have never been able to surpass a pressure of 220,000 atmospheres in the laboratory. Unfortunately, this pressure, the artificial production of which is an extraordinary feat, is reached at less than 310 miles under ground, not even one-tenth of the earth’s radius. Pressure continues to increase until it reaches 3.5 to 5 million atmospheres. In the equation of the earth, the effects of pressure will continue to be an unknown for a long time to come.

We have spoken of magma, of rigid, dense, liquid, hot substances joining in one catalogue the physical properties of the
matter in the interior of the globe. But all this does not answer the fundamental question: of what will the carrot-shaped sample of magma be composed, when the drillers of Project Mohole bring it to the surface? And, more generally, of what is the earth composed?

Without waiting for the results of the experiment, geologists have sought to penetrate the mysteries of the terrestrial globe by studying substances that have come out of the depths and surface rocks in the light of results supplied by the indirect method of observation. Classical geology, which studies the rocks on the earth’s crust, is still the basis for all possible deductions in this field.

**THE FAMILY OF ROCKS**

Before we follow geologists in their work, it is necessary to lay down the basic distinction between minerals and rocks.

A mineral is a chemical compound body, the elements of which are put together at the atomic level in the molecules. Its chemical composition is always the same and can be embodied in a formula. On the other hand, a rock is a mixture of minerals and has no chemical formula. It is an agglomerate, the composition of which can vary considerably from one sample to another. The decomposition of a rock can be a purely physical operation while that of a mineral supposes a modification of matter at the molecular level: a chemical reaction.

The basic mineral of the earth’s crust is silicon dioxide, or silica. Quartz, or rock crystal, is only a pure silica crystal. Two properties of silica should be noted: its lightness and its acidity. A rock rich in silica is acid and light. On the other hand, a rock having only a moderate amount of silica will usually be heavy and alkaline. Lastly there are rocks with very little silica, which are ultra-alkaline and very heavy.

How do the two fundamental rocks of the earth’s crust, granite and basalt, appear from the geological point of view? Note first of all that, when we speak of rocks on the planetary scale, it is question of rock families. The differences between these two rock families are distinct and easy to establish. From the point of view
of acidity, granite may contain more than 70 per cent silica, while basalt, which is more alkaline, has only 50 per cent. In granite the silica is associated with clear, light metals (essentially aluminium as well as potassium and sodium). In basalt heavy, dull metals predominate, notably iron and magnesium. Silica and aluminium are not very heavy. The density of aluminium silicate, in fact, is about 2.6 or 2.7. With less silica and aluminium and more iron and magnesium, basalt is heavier, its density reaching 3.

Calculation shows that rocks in the mantle must be heavier still than basalt. The diminishing proportion of light minerals like silica still reaches 40 per cent. The rocks become ultra-alkaline; on the other hand, the percentage of heavy metals, especially iron, must increase considerably.

We know of such rocks, and they are found exactly in all those places where we can expect to find samples of magma. Aerolites, i.e. meteorites which probably came from the mantle of a broken planet, consist of 87 per cent of the most common ultra-alkaline rock: peridotite. This is a substance which would suit the mantle very well, and the two minerals of which it is composed, olivine and pyroxene, will certainly figure in the Mohole carrot, with perhaps an equal amount of garnet.

In fact, all these minerals are found in lava. In 1955 samples were obtained from the volcanic St. Paul islets, in the mid-Atlantic volcanic zone. They were composed of peridotite. An analysis of lava from Hawaiian volcanoes has revealed the presence of olivine crystals. Particles of olivine have also been found in the holes which circle the Pacific from Japan to California.

Finally, samples of eclogite (a mixture of pyroxene and garnet) have been found at the bottom of diamond mines. Now the conditions of pressure and temperature necessary for the formation of diamonds can only be brought together at depths much greater than 3,000 to 6,500 feet, the level at which they were found.

So it seems probable that after the diamonds were formed at great depths, they were later pushed up toward the surface. It is natural to believe in these circumstances that the rock associated with them also came from the depths.

Geologists think that these minerals represent samples of
magma brought up with the lava without being subject to transformation, possibly as a result of more rapid crystallization.

Olivine, pyroxene, and garnet, then, are the most likely constituents of deep magma, i.e. the basic substances of the planet.

However, we must remember that these are subjected to fearful pressure which can change their nature completely. It is possible that new rocks are formed in such conditions. J.-D. Bernal put forward the hypothesis that under very strong pressure olivine could adopt an unknown cubic molecular structure.

As for the core, the metallic hypothesis, though very widely accepted, still has not won unanimity. It has been supposed that it enclosed hydrogen brought to the metallic state of pressure. Other geologists think that the entire globe is composed of olivine-type silicates and that the discontinuities registered below the surface are created by variations in the state of matter under the influence of pressure.

Finally there is this elegant, if unlikely, theory: the core of the earth is made up of one gigantic diamond, with a radius of two miles. The idea is so attractive that it need hardly be said that it has generally been rejected by specialists.

To return to the currently held theory, it seems likely that the core consists of a ball of iron or iron-nickel alloy. The fluid exterior of the core could contain light elements, especially hydrogen. Whatever is the case, it is certain that matter is in a dissociated state at this level. A ball of superdense plasma occupies the centre of the earth.

It is held that the basic substances of which the earth is composed, acid rocks, alkaline rocks and ultra-alkaline rocks, are rather alike and few in number. They are all, roughly speaking, mixtures of silicon, oxygen, iron, magnesium, aluminium, and some alkaline metals. From rock to rock we keep finding the same components, the only changes being in proportions and arrangements at the molecular stage. We can say that in each rock there is the material to make a specimen of any other at the very least. It is possible then that one kind of rock changes to another in the depths of the earth.
Heat and pressure could be the agents of such changes. Laboratory studies have been made of rock specimens which have been subjected to rigorous conditions of temperature and pressure. The results give an initial idea of what the chemistry of the deep earth could be.

Professor N. L. Bowen of the Carnegie Institute established that by making magmatic rocks crystallize, their different components could separate spontaneously. He collected superposed layers of olivine, basalt, and quartz crystals (pure silica). We see then that, by the effect of variations in temperature and pressure, ultra-alkaline rocks from the mantle can change spontaneously and free crust matter, like basalt and silica.

Heat and temperature can also cause changes at the molecular level. Professor Francis Birch of Harvard succeeded in changing feldspar (an acid mineral found in granite) into jade, which is an alkaline rock in a high degree. Thus a transition was made from a crust rock to a deep level rock.

These experiments prove that the phenomena of pressure and heat occurring in the earth can transform crust rocks to magmatic rocks, and vice versa. This chemistry also gives an elementary idea as to what moho is.

THE MYSTERY OF MOHO

The definition given of moho up to the present is purely seismological, namely that it is a level of acceleration of seismic waves. Yet we still have to find out why waves accelerate at this level.

We must exclude the point of fusion of rocks as being too simple an explanation. The temperature three miles below the ocean beds should not be more than 200° centigrade, whereas a good million degrees are necessary before rocks will melt. It seems more probable that moho represents the level at which certain conditions of temperature and pressure, which cause changes in the rocks, are brought together. Without knowing exactly what makes up this subterranean frontier, we may take for granted that it is neither fixed nor closed.

In fact, that the level of the moho varies comes from the definition itself. It is held between two very changeable regions
(changeable on the scale of a million years), the crust and the mantle. The evolution of the surface by erosion and the movement of magma make the physical conditions there vary constantly. Consequently the temperatures and pressures which characterize the moho vary with time.

This moving frontier is also an open frontier. Probably it is the region where rocks undergo physical and chemical changes fairly comparable to those produced experimentally in the laboratory. It could be a transit zone, which rocks pass over in both directions. According to the special conditions in each place and at each period of time, substances coming from the surface are changed into magmatic rock there and move down into the mantle, while magma undergoes the opposite transformation before coming up to the surface to become part of the crust.

**THE SKIN OF THE PLANET**

The earth therefore keeps on making and unmaking crust. What is the final result of this action? Is the earth’s crust becoming thicker or thinner? Geologists cannot give the answer, but it seems fairly probable that the thickness of the crust remains constant in the end, corresponding to a physiological state of equilibrium in the earth-organism.

This exploration of the moho has shown us the organic interdependence uniting the crust and the mantle. A moment ago we compared the crust to an eggshell, but if we push the comparison farther, it becomes radically false. The eggshell is only a package independent of its contents, while the earth’s crust, on the other hand, participates in the profound life of the planet.

From this point of view, a new comparison becomes possible: the earth’s crust is the skin of the planet. Between the mantle and the crust there is the same solidarity as there is between flesh and skin: an organic solidarity. Here is a primary illustration of the terrestrial unity we spoke of at the outset of this chapter.

This solidarity reveals the importance of the mantle in another way. The most powerful phenomena affecting the earth’s crust originate there. The rising of mountains, the movement of continents, and all the great deformations which mold the face of
the earth are evidence of the activity of the mantle. It could be said that the motor of the earth’s mechanism is located there.

It seems that the whole of the mantle does not participate directly in the life of the earth’s crust. The phenomena having repercussions on the surface originate essentially in the upper mantle (the first 400 to 600 miles). The exceptional interest of this region has resulted in the “Upper Mantle Project”, started by the International Geophysical and Geodesic Union.

The first observations show that physical and chemical conditions are extremely variable from one place to another. As magma possesses a certain plasticity, instances of disequilibrium must maintain all kinds of dynamic phenomena. We must await the results of studies under way to find out more about this essential organ in the terrestrial motor. For the moment, however, we shall retain the view that combined actions on and below the crust cause the earth periodically to make a new skin, forever rebuilding a crust constantly destroyed by erosion.

Terrestrial matter participates in physiological cycle in two phases, internal and external. The second is obviously better known because it is the easier to observe. All scholarly books contain descriptions of the mechanisms of erosion. The internal phase, on the other hand, still remains very mysterious, and all that can be affirmed is that it corresponds to a task complementary to erosion, allowing the whole structure to undergo changes over a course of billions of years.

**FUEL FOR THE EARTH’S MOTOR**

To raise mountains, shift continents and so on suggests a considerable expenditure of energy. What is the fuel which permits the earth’s motor to carry out this colossal task?

It seems probable that the earth draws its energy from nuclear fission, very like our atomic piles. We mentioned the presence of radio-active atoms disintegrating in rocks while discussing our radioactive clocks. This disintegration releases energy in the form of heat.

The heat is ejected through the rocks by conduction and is expressed at the surface by a flow of 40 calories per year per square
centimetre. It is established equally that the temperature rises some three degrees centigrade per 328 feet as you go down into the earth. Does this heat which is lost through radiation correspond to the whole of that produced by a terrestrial atomic pile? It is very hard to know because all rocks are not equally radioactive. At equal volume, granites release twice as much radioactive heat as basalts. Ultra-alkaline rocks are ten times less radioactive. Nevertheless, specialists think they can affirm that the earth's calorific production is distinctly greater than its losses. Part of the heat produced by the earth cannot be shed and in all likelihood, this part supplies the necessary energy for the earth-motor.

Numerous uncertainties exist as to the thermic state of the globe. For example, we do not understand why temperature increases less quickly in very radioactive granite soils than in basalt terrains; why the flow of heat is the same at the bottom of the oceans as on the continents, and so on.

We know very little about the temperature in the interior of the earth. It is thought today to be relatively low and not more than 10,000° centigrade at the centre. Most specialists think it is about 3,000°. This is certainly a far cry from the "central fire" of former times.

How does the earth's machine transform this heat into energy to work on the crust? Preserves cooking in a pan are constantly revolving. The overheated matter at the bottom comes up to the surface, and after cooling goes back down to the source of heat. This is only an illustration of a general law: every fluid subjected to a source of heat tends, by displacement of matter, to re-establish a certain thermic homogeneity in its mass. Now, there are certainly hot points and colder zones in the mantle. As magma behaves like a fluid over a long period, it is probable that currents of matter form just as in the potful of preserves. The vast majority of geophysicists believe that huge streams of magma, convection currents, run through the mantle.

Initial confirmation of this hypothesis was obtained recently by Bullard, an Englishman. By measuring the geothermic flow at the bottom of the oceans, he has established that it is two to six times greater than average in zones where hot ascending currents are believed to form. On the other hand, in regions which correspond
with descending currents of cold matter, the geothermic flow is flatly deficient.

As a result of the interdependence that unites the crust with the mantle, these huge streams deform and transform the terrestrial surface endlessly.

We know practically nothing about these currents except that they must be extremely slow—from one to four inches per year—and must have a very great width.
Earthquakes and Volcanoes

Tokyo, 1923: 38,000 exhausted casualties, having lost everything in the earthquake, were herded into a military camp while the town blazed. Suddenly the wind rose to gale force. In an instant the camp was engulfed in flames, and most of the occupants were burned alive.

Chile, 1960: in the district of Temuco, peasants, maddened by endless seismic disorders, returned to the customs of their ancestors and sacrificed a child.

Venezuela, 1949: after an earthquake, survivors found two arms sticking out of the ground like ghastly living plants. The hands were still grasping a child. In a last instinctive action a mother, trapped in a crevice, had held up her child before the earth closed over her.

Kansu, 1920: estimates varied between 200,000 and one million dead; 400 miners were buried at the foot of a shaft; 1,000 people were thrown into a crevice which was soon no more than a lake of dirty water. Whole villages disappeared forever with all their inhabitants.

Every year earthquakes kill from ten to thirty thousand people; it is impossible to estimate the damage caused by the devastation of towns and large areas of land. After each new catastrophe the question arises of what can be done to prevent a recurrence. Contrary to what the press often says, there is no protection in a better foreknowledge of the phenomenon. We can never know the exact location and date in advance. We will only arrive at probabilities. What would be the use of knowing that an earthquake is imminent in the region of Tokyo? Are we going to
evacuate millions of people? By so doing, we would be simply risking useless panic.

Actually we can protect ourselves against earthquakes very well today by simply constructing buildings according to the rules of anti-seismic architecture. Tests prove that such erections can stand the most violent shocks. Unfortunately the economic means and the techniques of para-seismic engineering do not exist in most of the countries threatened. This is why earthquakes will continue to kill in the future.

THE TYPICAL CATASTROPHE

An earthquake may be defined as the shock caused by a rupture in the deep layers of the crust following tension that exceeds the limit of resistance of substances.

Suppose you are holding a branch of green wood and you bend it. For a long time it will resist your efforts, bend like an arch, then suddenly it will snap. If you use all your strength at this moment, you will feel an almost painful shock running through your whole body. An earthquake is no different. Tension builds up in rocks (tension or compression), as in our branch of wood; the substances resist, then break suddenly. The energy released is expressed by a shock which spreads to the surface.

Warning tremors often come before great catastrophes. Animals are said to be specially sensitive to these. At the time of the earthquake in Messina in 1908, some actors who had come to perform there were wakened in the middle of the night by the barking of their dog, Menelik. As the animal refused to be quiet, the occupants of the hotel finally went out into street to find what was causing the barking. They were hardly outside when the earth began to tremble and the hotel caved in.

Many stories of this kind are known, but they need confirmation.

The earthquake itself usually consists of several shocks. In the Chilean crisis of 1960, the most violent ever recorded in history, shock followed shock for a month, practically without interruption. Earthquakes are followed by weaker tremors, or "replies".

The violence of an earthquake can be estimated from two points
of view: from the damage done or in terms of the energy released. The two do not correspond. If the breaking point of the rocks is at a great depth or if it occurs vertically below a desert region, an earthquake can release enormous energy without loss of life. This was the case in the great earthquakes at Assam in 1897 and 1950. On the other hand, a shock of small energy, like the one at Agadir, where the breaking point was very near the surface and right under the town, killed 10,000.

If we judge an earthquake in terms of the destruction it causes, we define its intensity, which can vary from I to XII for great catastrophes. The energy released lets us measure its magnitude, which can reach 8.9 for great earthquakes (which are not automatically the most destructive). A shock of a magnitude of 8.9 does not mean much to the layman. To make it plain, let us say that in the case of an earthquake like that in Alaska in 1964, the energy released corresponds to that of one thousand atomic bombs. The most violent earthquakes must have the power of 100,000 atomic bombs.

The destructive effects of earthquakes depend on the sturdiness of buildings and the nature of the ground supporting them. The earthquake at Messina is particularly instructive in this regard. In spite of previous disasters, the city had been built with poor materials and on crumbling alluvial ground. This is why an average shock can kill a hundred thousand people. A shock of the same strength hitting a properly built city would cause a few thousand deaths at the very most.

Earthquakes are accompanied by sound and light phenomena which are not yet satisfactorily explained. During shocks a very powerful rumbling seems to come up from the earth. We have learned that these noises are caused by the vibrations of the surface which produce sound waves as they strike the air. On the other hand we do not have an explanation of terrestrial lightning, the very existence of which was long disputed, but which has today been corroborated by abundant testimony. At the time of the earthquake at Izu in Japan in 1930, fifteen hundred people, including several scientists, saw the sky lit up by numerous flashes. Yet there was no storm in the air, and these phenomena did not correspond to short circuits caused by the breaking of high
tension wires. Specialists still do not know whether they are electrical or magnetic phenomena.

Generally, eyewitness accounts are listened to very carefully by seismologists, for apart from the understandable panic which does not favour objective observation, it seems that at these moments man is prone to seeing mirages of some kind. Haroun Tazieff cites the case of an engineer who says he saw a factory smokestack undulate. Yet, in spite of a minute examination, no fissures were found in the bricks. In 1918, Dr. Anderson, of Mount Wilson Observatory, saw a concrete embankment crossed by waves eight inches wide. After the earthquake he inspected the concrete with his magnifying glass without being able to find the smallest fault. It may be that these hallucinations are caused by shocks to the nervous centres. On the other hand, they may be attributable to electrical phenomena. It is still one of the mysteries that surround earthquakes.

Earthquakes which strike great cities are often followed by huge fires. Tokyo and San Francisco suffered much more from fire than from the shock. At San Francisco less than 10 per cent of the damage was caused by the latter. It was long thought that the earth “spat fire” at the time of these convulsions. We know today that it does nothing of the kind. These fires are caused by domestic fires in homes knocked over. In Tokyo, in 1923, 76 fires broke out at the same time. The fire blazed for three days, nearly half of the city was destroyed, and 22 firemen perished. Unfortunately, fire-fighting is very difficult in a striken town. The earthquake usually bursts water mains. Without water, the only effective fire-fighting methods are dynamite and counter-fires which often prove very dangerous.

In 1868 the American warship Wateree was anchored off the Chilean coast when an earthquake took place. The sea became rough and the sky was darkened. In the middle of the night the ship, caught in the tempest, was lifted by a wave 75 feet high. The ship could not fight against this monstrous force sweeping it along. Miraculously it did not sink, and even better, not one man was lost. Finally it lay in a calm and peaceful zone. The men then ventured on deck and tried to repair the damage by lamplight.
Their ship was resting on dry land, aground on a reef, so they thought. But at daybreak they saw that they were lying inland. The ship had been carried two miles from the shore, fifty feet above sea level. A few miles away rose the near ranges of the Andes.

Earthquakes often cause tidal waves, or *tsunamis*, as scholars call them. This was the case at Lisbon, San Francisco, Tokyo, and Chile especially. These huge waves, which can reach up to eighty feet in height, evidently have nothing to do with tidal phenomena. The colossal wave is produced by the sinking of the sea-bed following earthquakes. It travels at a speed of several hundred miles per hour to come battering against shores sometimes several thousand miles away from its point of origin. Japan and the Hawaiian Islands were ravaged in this way by a tsunami after the 1960 earthquake in Chile.

The residents of the Pacific coasts are quite familiar with tidal waves, from which they have often had to suffer. In Chile, when the cry goes up, “*El mar se retira*” (The sea is going back), the inhabitants know that they have only a few moments to flee the coast and take refuge on high ground.

The tsunami begins with the sea retreating. The whole shore is left dry. A few minutes later, the sea comes back at the speed of a galloping horse, raised in a wall of water 65 feet high. As it beats the shore, it destroys entire villages up to several miles inland. There is only one possible defense: flight.

Today this last recourse is within man’s reach. On the initiative of the American Coast and Geodetic Survey, a Tsunami Warning System was set up in the Pacific. When a tidal wave forms, threatened regions are warned by radio. Unfortunately, the inhabitants are not yet accustomed to the system. If it worked well in 1957 in the Hawaiian Islands, it did not in 1960 at the time of the Chilean earthquake, the tsunami killing some 250 people in Hawaii and Japan. Yet Valparaiso had alerted Honolulu and Tokyo normally, and they had warned the coastal populations. Unfortunately they did not take the warning seriously and stayed on the shore to wait. When they saw the wave arriving it was too late.
A MOTOR AT WORK

To most people an earthquake is above all a drama; to geologists it is a tectonic phenomenon, i.e. a manifestation of the internal workings of the earth. The terrestrial crust is crossed by huge furrows along which the "earth-motor" works. These generally correspond with faults.

One of the world’s most famous is the San Andreas fault which runs 560 miles along the west coast of the United States. Periodically, earthquakes make it act up again. At the time of the 1906 earthquake the western part moved up to the north, while the eastern zone moved down to the south. This shifting, which is easy to see by following the lines of roads and railroad tracks, amounted to 23 feet.

The work of earthquakes is carried on in the vertical just as much as in the horizontal plane. In Tokyo in 1923, the shore was raised 25 feet, then subsided to five feet below its former level. In Assam in 1897, a section of a fault rose 36 feet for a length of 12 miles. The entire coast of Alaska was raised 46 feet in 1899.

These movements involve entire regions. Tokyo’s roadstead subsided in 1923. In places the lowering of level amounted to 820 feet while the sea bed rose in other places by the same amount. In Chile, Haroun Tazieff estimates that a region of 3,800 to 6,700 square miles sank down 5 to 7½ feet. The line of the fault being probably at sea, the subsidence must have been still more considerable there.

The subsidence of ground caused by earthquakes can, in rare instances, have happy results. The port of Barranquilla, Colombia, was wasting away because the channel was becoming blocked by a sand bank which kept getting bigger. As a result, ships of average tonnage could no longer reach the harbour. On the morning of July 11, 1963, the inhabitants saw to their utter amazement, that the channel, the depth of which had gone as low as thirteen feet, was once more accessible to the biggest ships. All of a sudden the depth was 257 feet. It was established that this subsidence had been caused by an earthquake that had happened the night before, but which had passed almost unnoticed in that perpetually disturbed region. Since then the port of Barranquilla has recovered normal
activity, and the people have decided to make July 10, the day of the earthquake, a day of thanksgiving.

Ground tremors, again, modify the surface of the ground by causing avalanches and landslides. At least a thousand such slides occurred at the time of the great Chilean crisis. When the ground is especially crumbling, the topography can be completely modified. In 1920 the inhabitants of Kansu did not recognize their country. The hills had changed their shape and place. A missionary cited the case of a peasant who had built a cabin on the top of one of these hills. During the earthquake the hill was dislodged but the little house stayed where it was. After the catastrophe had passed he was still living on his hill, but a half mile away from where he had been before.

From observations of the earthquake in Chile, Haroun Tazieff established a much more disturbing phenomenon. Huge masses of land had been displaced on to absolutely horizontal surfaces. Having been torn from very low hills this material could not have moved only under the impetus gained in its fall. It seems to have been set in motion by the vibrations of the ground. This phenomenon, not known till now, could explain, among other things, the lateral displacement of geological layers after their deposit and the displacement of continental sediments at the bottom of the oceans.

THE BIRTH OF MOUNTAINS

Lastly, a very significant geological task is carried out by the earth through earthquakes. Professor Goguel believes that the great faults and vertical shiftings of hundreds, indeed thousands, of feet could not have come into being on a single occasion. The faults have acted by series of successive jerks, each of which caused an earthquake.

Thus, the effects of successive shocks accumulate, acquiring extra-ordinary proportions over millions of years. Probably the earth is changed as much by abrupt movements as by slow, imperceptible deformations.

Seismologic advances have made it possible to determine the depth at which earthquakes originate. If the majority are caused by
ruptures occurring in the crust, some begins much deeper (as much as 465 miles). They denote the mechanisms at work in the mantle and are in relation to the deep dynamism of the globe.

This gives us a glimpse of the part earthquakes play in the general work of the earth. Professor Rothe, one of the foremost world authorities on seismology, has written: “To seek the cause of earthquakes is to seek the cause of the movements of mass in the deep interior. . . . We do not know why mountains rise, and as long as we do not we will not know the real fundamental cause of earthquakes.”

It seems that the origin of mountains is to be found in immense ditches of great depth which run the length of continents: geosynclinals. Sediment brought by continental erosion accumulates in these depressions. The mass of matter can be more than six miles thick. Then by the action of horizontal forces, which compress it, and of vertical forces, which push it upward, the accumulated sediment rises up and forms mountain chains. All this work is accompanied by intense seismic activity. Mountains are already very old when earthquakes stop in their region. During the process the matter is the toy of colossal forces which heap it up, compress, fold, draw it down to the depths, or on the contrary lift it up.

We have defined earthquakes as ruptures in the deep layers following tension. This tension is caused precisely by these forces which raise up mountains. It is therefore a geological postulate that where mountains are erected there are earthquakes. In these regions the matter is subject to considerable compulsions. Inevitably the rocks will break, despite a certain elasticity, and then a fault is produced. For a while the two planes of the fault will find a position of equilibrium and will be, as it were, soldered together. But the tensions will start building up again. It is common knowledge that a substance always yields at old fractures. The same applies to the deep layers of the globe. Geologists say that the fault is acting up again. When the tension ceases, i.e. when the mountain is already tens of millions of years old, the fault will be repaired for good. The region will have become safe to live in.
IS THE SUN TO BLAME?

Tensions can exist even in the superficial layers of the earthy crust. In quarries it happens that blocks of stone explode when they come out of the rock, as a result of the tensions to which they had been subjected.

Why do rocks subject to tensions give way at one moment rather than another? To be sure, the simple working of tensions progressively accumulating will finally cause rupture. However, it seems that things do not happen in exactly this way. When tensions approach the point of rupture, the slightest force upsetting this unstable equilibrium between the two opposing compulsions unleashes the catastrophe. Professor Rothe gave the name “trigger-force” to this accessory force which, so to speak, is the spark that sets off the earthquake. What could be the nature of this force?

By studying microseismic activity since the beginning of the century, Pierre Bernard, a Frenchman, discovered that it seemed to follow an eleven year cycle. Eleven years is the cycle of solar activity so why not make the comparison? However, contrary to what one might have thought, microseismic disturbance reaches its maximum not during years of intense solar activity, but in periods of solar calm.

Stoyko and Mironovitch have tried to find out if there is a connection between seismic activity generally and solar activity. They have discovered disturbing coincidences, but it is still too early to draw firm conclusions from them.

It would be possible that disturbances caused in the earth’s rotation by solar activity could, in certain cases, constitute the trigger force of earthquakes. There is nothing unlikely about this. The earth consists of successive, more or less plastic, layers. They would certainly not react uniformly to a braking effect. Such a slowing down would create tensions between the different levels. These forces, though very weak, could be enough to set off seismic crises.

We have also noted that earthquakes are often preceded by magnetic and gravitational disturbances. Research is under way on
all these points, and the exact nature of these mechanisms will not be known for some years.

Russian scientists, notably V. Obrouchev, believed it was also possible to establish a relationship between the seismic action of the earth and the movements of the moon. It seems that earthquakes occur more readily when the moon is at its perigee (i.e. nearest the earth), and at the meridian of the location of the catastrophe. The periods of full moon would likewise be very dangerous for the fragile zones of the earth’s crust. Are we to think that the moon’s gravitational field makes itself felt with more force in certain preferential conditions? If so, it could disturb the currents of matter in the internal magma. Certain atmospheric disturbances (storms, heavy precipitation, etc.) could also induce seismic crises.

It seems certain, therefore, that trigger forces frequently unleash earthquakes, but they can be very different in nature and our knowledge of them is still very imperfect.

**The Earth Spits Fire**

Besides earthquakes, the distressed regions of the world often suffer as a result of volcanic eruption. On the scale of the loss of human life, these disasters are infinitely less serious! In the course of the last five centuries, volcanic eruptions have resulted in less than 200,000 fatalities. The phenomenon, however, seems to have played an important part in the history of the terrestrial crust.

Volcanologists today can foresee a volcanic explosion with nearly total certainty. Before an eruption, many telltale signs appear. Microseismic agitation increases considerably. The rising lava swells the volcano. Also, the field of gravity registers the workings of the volcano.

In recent years, American scientists have followed the volcanic mechanism of Hawaiian volcanoes with great accuracy and have foretold every eruption. But to do this, the volcano must be equipped. That is, an observation post must be installed with the necessary equipment and qualified personnel. Obviously, such observation posts do not exist for all volcanoes, either active or liable to become active again.
Once volcanologists know that a crisis is in the making, it becomes relatively easy to evacuate the people, for the centre of the expected catastrophe can be localized with high precision, which cannot be done in the case of an earthquake.

On May 8, 1902, Mt. Pelée exploded in Martinique. A fiery cloud struck the town of St. Pierre, killing 26,000 people. This tragedy should never have happened. Many warning symptoms had appeared several days previously. Unfortunately, the radical measures necessary were not taken. The evacuation of threatened communities was hindered by political considerations!

The greatest danger in volcanic eruptions is still the tsunamis which they can cause.

On the 26th and 27th of August, 1883, Krakatoa (a volcanic island in the narrows of the sound between Java and Sumatra) exploded. The deflagration, which released 5,000 megatons of energy (comparable to the energy of a thousand H-bombs), was heard 3,100 miles away. The island was completely pulverized. The disaster brought on a tsunami which killed 36,000 people. Five billion tons of ash was belched forth to a height of twenty miles. At Batavia (ninety miles from the site of the explosion) the sky was covered by a black cloud and the city was plunged in darkness in the middle of the day. For years the atmosphere was “dirty” all over the world. Sunsets became unusually red. Three years after the explosion, the ash still kept back 10 per cent of the sunlight.

Such disasters are relatively rare, but it is probable that they were infinitely more frequent and above all more violent in the past. In our time the craters of active volcanoes hardly exceed six-tenths of a mile in diameter, while the mouths of former volcanoes measure tens of miles. These eruptions caused gigantic flows of lava. In India the Deccan plateau, over an area of 270,000 square miles (the area of France is 212,300 square miles), was covered by a layer of basaltic lava six-tenths of a mile thick! In all regions we have found traces of powerful volcanic action which brought huge quantities of magma to the surface.

A volcano like Krakatoa manifested its activity by an explosion which completely disintegrated it. On the other hand Hawaiian volcanoes pour out torrents of lava without exploding. The
magma overflows the crater very quietly and in profuse streams and spreads over the slopes of the volcano where it solidifies, enlarging it with a new layer.

Between these two extremes, the family of volcanoes comprises all intermediate types. Each of the 485 active volcanoes in the world has been methodically studied and classified by volcanologists. It is very hard to say when a volcano is definitely dead. For example, Bezymianny, a huge volcano in Kamchatka, considered definitely dead, came to life again in September, 1955. It finally exploded in March 1956, causing one of the most violent eruptions ever recorded.

The kind of eruption, explosive or peaceful, depends on the type of lava poured out. If the matter is extremely viscous, its expulsion can happen only after an explosion. On the other hand liquid lava will glide quietly down like genuine springs, as can be seen in Hawaii.

The viscosity of lava depends on the percentage of silica. This can vary from 76 per cent in rhyolites to less than 50 per cent in basalts. In the first case the lava will be very viscous, in the second very fluid. Things never being simple in geology, this outline is enormously complicated in nature, and successive eruptions of the same volcano are not always of the same type. A long dormant volcano can thus explode before pouring out fluid lava.

AN UNCERTAIN MECHANISM

In outline, a volcano could be described as a local accident in the crust which connects the surface with a pocket of fluid magma.

The discovery of these wells of liquid magma was made recently, thanks to seismic studies, by the Soviet volcanologist G. Gorshkov. By studying the volcanic system of Kamchatka, he showed the presence of a pocket of liquid lava some 20 miles long, situated at a depth of 37 to 43 miles. A seismological study of Hawaiian volcanoes has shown that their lava came from a similar depth. In the latter case, Mohorovicic Discontinuity passes 8.7 miles beneath the surface. The volcanoes therefore draw their lava directly from the mantle.
Lava comes to the surface usually by taking advantage of a fault system. In Chile, for example, all the volcanoes are in a straight line 930 miles long, obviously marking a fault in the earth’s crust. In certain cases the lava never reaches the surface. A magmatic intrusion into the crust occurs, which later solidifies.

Different explanations have been offered as to how these pockets of liquid lava form, but no certainty exists. It is conceivable that a local diminution of pressure lowers the fusion point of the rocks, which would suddenly become liquid. But we do not know what could originally cause such a fall in pressure. Is a rise in temperature caused by a release of abnormally high radioactive heat? How could such a phenomenon occur in the basaltic mantle? Convection currents also have been considered. Hot rising currents would be found below volcanoes. The hypothesis seems probable enough for the Atlantic ridge.

It still remains to determine the force capable of lifting tons of lava over tens of miles. American scientists believe that it could be caused by a pressure difference, this being weakest beneath the crater. Gases seem to play a determining role in the rising of the lava. The phenomenon would resemble the overflowing of champagne under the pressure of the carbon dioxide which escapes from the bottle when opened. These gases must be released by a whole series of chemical reactions and physical changes of matter. We know, for example, that the opposite of ice, rocks increase in volume as they melt. If they crystallize, on the other hand, they release volatile elements and some of their water.

In fact, water seems to play a deciding role in volcanism. It has long been thought that it filters through faults beneath the oceans and reaches overheated magma. At this level the pressure of water vapour would perform an essential motor function. It is a fact that volcanic exhalations contain huge quantities of water vapour (90 per cent according to some authorities). But no one knows whether this water comes from the oceans or is discharged by the magma.

Why are there volcanoes? What is their role in the general functioning of the earth? Geologists cannot give the answers. All they can say is that, like earthquakes, volcanism participates in a decisive way in the general functioning of the earth and that its
role is much more important than was thought some decades ago.

K. Sapper, a geologist, tried to add up the volcanic activity of the last five centuries. Retaining only very moderate figures, and supposing that this activity was always kept at its present rate—we have seen that it was certainly much more considerable in the past—he reached the conclusion that the production of lava in the course of the geological ages must have been sufficient to cover the continents with a layer nineteen miles thick.

This conclusion may appear surprising, since the continents do not consist of vitrified lava, but of granite and sediment. However, there is nothing unusual in it because once the rocks are brought to the surface, they are caught up in a cycle of changes which will necessarily make them become granite or sediment after some tens of millions of years.

Moreover, we can apparently take for granted that volcanism, especially intense when the earth was young, released the elements of the atmosphere and the hydrosphere.

In our time volcanoes are generally found on the active zones of the terrestrial crust where mountains rise. Although not absolute, the rule of the agreement between seismic zones and volcanic zones has been very substantially verified. However, the relation between the two phenomena is still a mystery. It is rare for an earthquake to arouse volcanoes, and, likewise, volcanic eruptions cause only slight tremors, very different from great earthquakes.

Lastly, there are purely volcanic zones where the geosynclinals that are the forerunners of mountains are not found. This is notably the case with oceanic volcanoes, like those in the middle of the Atlantic and in Hawaii. In this case the volcanism doubtless corresponds with a fracture in the basaltic carpet of the oceans under the influence of hot currents of magma.

There seem, therefore, to be two kinds of volcanoes: those in seismic regions, in the zones where the deep faults and the geosynclinals are found, and those which appear in the middle of oceans.
A rapid flight over our planet will show us the marks of its internal dynamism on its physiognomy, but to be informative the trip must be organized and planetary in nature.

We shall ask the life of the earth itself for the itinerary. From this point of view the terrestrial surface can be divided into different zones, some very active, others moderately active, and still others quite dormant.

The world’s activity will be made clear only if we fly very high, and if we have a really planetary view of it. We shall therefore have to obliterate as many details as possible in order that the dominant features of the earth’s face may stand out. What we gain in simplicity we shall obviously lose in precision, but respect for details in the ordering of great syntheses is a luxury reserved for the greatest scholars.

The important thing is to bear in mind that the outlines which will stand out during this trip are simplifications and considerably distort an infinitely more complex reality.

There are stable zones on our earth. Such regions are found on all the continents, but in principle only one exists for each continental block. They are called shields. Here the rocks are very old and have been smoothed to such a degree by erosion that all broken relief has disappeared. The landscapes consist of plains, near-plains and plateaus. This observation already lets us single out a first geological law: the oldest terrains are also the most stable. It is the same with continents as with people: they become calm as they grow old. A continental block set in place for billions of years does not move any more.
Each continent has its shield; here is proof. The shield of the Euro-Siberian block is in the northwest, embracing most of Scandinavia, north Russia and northwest Siberia. Africa has its shield in the central southeast. North America’s is in eastern Canada, and South America’s on the Brazilian plateau. In South Asia we find these quiet old regions in the Indian peninsula, in Borneo and in Indo-China. As for Australia and Antarctica, they consist of practically nothing but ancient rocks.

These are the calm regions of the world. Here nothing spectacular happens, no earthquakes or volcanoes or fractures, nothing but slow erosion and some rising or falling movements corresponding to isostatic readjustments—an arid field of research for scientists. All the more so, since the grindstone of erosion has implacably effaced the traces of the past, rock changes have removed all fossils, and events to be reconstructed go back billions of years. So we should not be surprised that we know very little about the formation of these regions. The granite massifs which still remain in place are remains far too doubtful for us to be able to tell whether they were originally made of granite or basalt, or if they constituted the first relief to come up to the surface of the earth.

On the continents we also find less stable regions than these immovable shields. Their inhabitants sometimes see lights swing to and fro or hear clocks strike at the wrong time, but the shocks rarely have the force to knock down buildings. Western Europe in general and France in particular give a fairly typical picture of this slightly seismic zone. The most violent earthquake France has had in a hundred years goes back to 1909. It shook Provence and killed forty people. That is a long way from the Japanese or Chilean disasters.

THE CONTINENTAL FRACTURE SYSTEM

The system starts from the western Antarctic where two volcanoes lie lost in the ice: Erebus and Terror. It moves north with a swing to the east, under Tierra del Fuego, then it follows the South American continent along the Andes. In Central America, it takes a new turn eastward and the active zone embraces the
Antilles in the Atlantic. It then passes up the Pacific coast of Mexico and by the Rockies to Alaska. There it swerves to the west and, by way of the Aleutians, joins Kamchatka. From there the descent begins along the coasts of southeast Asia, the Kuriles, and Japan. At this latitude the system branches in two directions. One branch moves out to sea toward the Philippines, while the other goes along the coast by the Ryukyu islands. The two lines join up again off Indonesia; the active zone then moves west, cuts through New Guinea, winds round Australia by a series of archipelagos and joins New Zealand again. Thus our tour of the Pacific buckled, so to speak. It is the famous "ring of fire." It has the grim privilege of monopolizing 75 per cent of the earthquakes of some significance and almost all the deep earthquakes.

This wide belt is joined by the mountainous transversal which, leaving the Atlantic shores in Spain and North Africa, circles the Mediterranean, and is continued through the unstable zones of South Eastern Europe, Turkey, Iran, Afghanistan, and the Himalayas. The system then descends to the Bay of Bengal, follows Burma and the Malacca peninsula, and rejoins the Pacific belt between Borneo and New Guinea. Why are regions as different as the American Cordilleras, the rings of Asian islands, and the Himalayan chain encompassed within the same system? Is there really any continuity over the terrain between these different zones? A detailed study of these distressed zones shows that they do indeed form a geological whole, presenting the same characteristics throughout, the most striking of which is that it is made up of a series of arcs of a circle which fit each other. It is particularly easy to demonstrate this for the garland of Pacific islands. The Aleutians, the Kuriles, the Ryukyu islands, and so on, are never in a straight line, but always in a curve. The observation holds good also for the Cordilleras and for the Alps-Himalaya system. Certainly, the rule is only an approximation; in certain places we do not find these curves, but we know that a geological law is never verified with geometric rigor. The pattern of the arcs none the less has a distinctness in the total system which is absolutely extraordinary for a geological phenomenon.

There is a second impressive law: these arcs are bordered on the convex side (the convexity always faces the sea) by deep oceanic
ditches. The rule is verified by the whole Pacific belt. Obviously it is not found in the Alpine system, but the Euro-Siberian bloc was once separated from Africa and South Asia by a transversal sea, the Thethis, of which the Mediterranean forms the last remains. Before this oceanic basin closed up, would not the same arrangement be found?

At the vertical of the oceanic ditches we find that weight is distinctly reduced, an observation all the more striking since weight anomalies are generally positive in the sea; the geothermic flow is also less there than the average.

Gravimetric measurements have played a decisive role in the discovery of these geological structures. For a long time the observation of weight at sea posed an insoluble problem. It was not resolved until after the 1914 war by the Dutch scientist F. A. Vening-Meinesz. To attain his objective the geophysicist had first to perfect a new gravimeter with a double interval which could be used at sea. He then decided to make a gravimetric voyage by submarine. The vicissitudes of this voyage put it on a level with the most extraordinary explorations.

Vening-Meinesz and his assistant, Harry Hess of Princeton University, had at their disposal only the most ancient vessel belonging to the U.S. Navy, the S-48 which was generally considered a floating coffin when they embarked in 1932. Four times in one month the enterprise came close to ending in disaster. The first time, the navigational mechanism got blocked up, and the vessel plunged toward the bottom. It could only be straightened out at a depth of 1,100 feet: a dangerous record for such an old carcass. The return to the surface was so rough that the scientific equipment was damaged and had to be changed. It was repaired, and the scientists tried again.

This time the disaster almost occurred, not in deep water, but on the surface. The vessel was performing a dive in a generally deserted area. As it was about to surface, to his horror the captain saw in his periscope the huge mass of a ship only a few metres directly above the submarine.

Over tens of thousands of miles we find the same geological system, repeated from arc to arc. What does one of these arcs look
like? If we approach it from the ocean, we encounter first the oceanic ditch, with its abysses several miles deep, which marks the beginning of the unstable zone. As we continue to approach the continent, we reach the island ring. Here volcanism is intense. Then, between the archipelago and the continent, a shallow arm of sea, the epicontinental sea, extends where continental sediments pile up. Finally we arrive at the continent. The zone is already much less seismic than on the islands. If we penetrate inland, we finally reach completely stable land.

Geologists think that each arc corresponds to a huge subterrannean fracture. It begins under the continent at a very great depth, then comes to the surface according to an inclined plane making an angle of 60° with the surface. It arrives at the surface at the bottom of the oceanic ditch. This fault, as it works, causes earthquakes, which at each point come into being at a depth corresponding to that of the plane of the fault. Consequently earthquakes are superficial in the open sea and deep under the continent.

Geophysicists cannot say for certain what the significance is of this series of fractures along the continents, but this does not hinder them from constructing theories.

We must recognize that an imposing coherence stands out from this planetary structure, which could not be accidental. Let us superimpose on to a map of the world our shields, the intermediate zones, and then the long active bands. We notice that on the American continent the fractured zone runs to the west. The shields are to the east in both hemispheres, therefore at the farthest possible distance from the distressed regions.

The Euro-Siberian bloc forms a kind of diamond, two sides of which are fractured (the Alpine transversal and the Pacific Coast). We find the shield right at the top, again as far as possible from those unhealthy parts. The same is true for Africa: the wise and solid old rocks are in the south, and the fragile band in the very north.

We therefore always have pretty much the same outline on each continental bloc: a very old and very stable shield in the area farthest from the young, active zone. This arrangement irresistibly suggests the progressive formation of the continents. Starting from the continental cores, the lands which emerged would move
forward gaining progressively on the ocean basins. The continents would be in constant formation.

This is the point we can reach in theory. For we are dealing with pure theory here, and as such the American geophysicist Walter H. Bucher advances these ideas. It seems, moreover, that many Anglo-Saxon geophysicists are tending toward a conception of this kind.

It is difficult for one who has not read the geological treatises of the last century to conceive what a monstrous heresy this theory represents. It was then held that the continents had been formed at the beginning and since that time some of them had disappeared rather than appeared. The ocean basins corresponded to a constant sinking of the earth's crust.

All this venerable knowledge is now being called in question. The problem is no longer one of sinking ocean basins, but rising continents. As for the latter, instead of appearing with the first solid crust, then sinking and becoming progressively wrinkled, they are growing up and spreading constantly (which does not exclude the collapse of continental sections).

The planet which Suess saw as being in the act of falling to pieces, modern geology represents as young, dynamic, and going strong. Synthesizing the views of such authorities as Griggs, Holmes, Vening-Mcinesz, etc., Professor Tuzo Wilson holds that each fracture corresponds to a construction site on which the earth erects a mountain. When the edifice is completed, or rather let us say when the mountain stands solidly erect at the edge of the ocean, a new fracture occurs off the coast according to a fresh arc situated in front of the preceding one. This new arc fits in with the whole system, which can therefore move forward by local thrusts, while all the time presenting a united front facing the oceans.

What will take place on this new construction site which the earth has just opened? Professor Tuzo Wilson thinks that the ocean bottoms sink forming a deep trench according to the leveling line of the fracture. When this happens too near the coast, currents of mud circulating on the ocean floor will bring there sediments torn off the continent. In this way the trench can fill up. The sediments eventually fill up the fault, and accumulate as they are no longer being drawn down to the bottom. But along this
trench the weight is too small; now, the earth does not like disequilibrium and keeps working to counteract it. In the present case it will restore the weight to a normal level by raising the sediments at the bottom of the trench. It is an isostatic readjustment. A ring of islands formed from sediments thus emerges on the site of the trench.

On the other hand, if the construction site has been opened well out to sea, the continental sediments will not be able to fill up the trench, since a barrier, a volcanic chain, will rise between it and the shore. Soon volcanoes come out of the water, grow, and eventually form an archipelago. Their activity gives these islands considerable dimensions in the course of thousands of years. This is why the youngest, like the Aleutians, are slender, while old ones, like Japan, with hundreds of millions of years behind them, are of considerable size. These volcanic islands will begin to undergo erosion. Their sediments mix in the epicontinental sea, that is, the portion of sea comprised between the ring of islands and the continent, with those which come from the continent. Thus, the China Sea is constantly being filled up with the huge deposits from the Yangtse-Kiang and Hwang-Ho rivers. Then the whole structure will start to rise. Although the mountains do not rise with the speed of stage scenery—contrary to the belief of the great cataclysmics—it seems that growth is very rapid here for a geological phenomenon. For example, on the island of Timor Quaternary corals have been found at an altitude of over 3,000 feet.

Soon the epicontinental sea will have disappeared and the continent will have gained some tens or hundreds of miles. To put such a mass in equilibrium is obviously a colossal feat.

In the uncertain sub-basements there are ceaseless disequilibriums, and the mountain shakes periodically in the course of millions of years. At last it finds its equilibrium. By then it has rounded shapes and its period of splendour is past. During this period, however, on the continental front, the struggle continues by leaps and bounds.

Theory would evidently require that the aim of earthquakes is to make the readjustments necessary to put the mass of the mountains in equilibrium. But observations made after the violent earthquake in Assam in 1950 make us wonder if the earth
recognizes this theory. Gravimetric measurements carried out in
the Himalayas had shown that this mountain was 650 feet too high
for perfect isostatic readjustment to be realized (according to an
estimate by Daly). It could therefore be supposed that the effect of
earthquakes in this region was to cause subsidence. But, after this
earthquake, it was established that the shaken region of the
Himalayan massif had risen 100 to 130 feet. How do we explain
an earthquake having the result of accentuating the disequilibri-
um of the earth’s crust? Did a force more powerful than isostasis
exist in that part of the world? It is probable, but no one knows
its nature.

WHAT RAISES THE MOUNTAINS?

The geologist following the trail of the “agent of orogenesis”
(the learned name for the force which lifts mountains) can take
two paths, one vertical, the other horizontal. Either the force that
raises mountains acts only following the vertical, it is only a move-
ment upward, or, on the contrary, the effort is exerted on a
horizontal plane and compresses substances till they wrinkle and
then rise. Both explanations are equally logical and no less
convincing than a third supposing that our agent of orogenesis is
twofold, like every agent, and acts on both the vertical and
horizontal planes at once. The gigantic oblique faults irresistibly
suggest a horizontal thrust of the continents. Is it because currents
make them shift? We reserve this question until later.

It is no less certain that at one stage or another of “the geological
drama”—Professor H. Termier’s apt expression—the vertical
forces of isostasis intervene, which raise the structure to counteract
the weight disequilibriums of which the earth shows everywhere
its abhorrence.

May one not believe, after all, that the mountains “swell” as they
form, just like a piece of dough? No science fiction is involved in
this theory. The phenomenon is at once probable and highly
mysterious: “the greatest mystery of geology”, even the specialists
call it. The mystery has a name: granite.

In actual fact all continental bases and mountain cores are made
of granite. Now no one knows where this rock comes from. There
used to be a picturesque formula to conceal this ignorance, and it
was said that granite was "the dross of the primitive crust".

Granite differs from sedimentary rocks in that it forms a homo-
genous unstratified mass. When a granite massif is found in a
sedimentary formation, the layers are neither wrinkled nor raised
up by the granite intrusion.

It seems that a mysterious hand removed sediments, then
placed the granite in the hole. But on the other hand, all round the
granite massif the rock underwent transformations which brought
it near the state of granite. Granite is contagious. What place can
these strange phenomena have in the life of the rocks?

Every rock on the earth's surface is doomed to become sediment.
It will then be transported and piled up in communal geological
ditches, of which the commonest are the geosynclinals. The piling
up of sediments will compress them and thrust them down to the
deep interior. The sedimentary rock will then undergo a whole
cycle of changes called metamorphism. It was traditionally held
that at the end of this metamorphosis the sediments reformed a
homogeneous crystalline rock of the gneiss family, that is, a rock
very close to granite.

But it was generally believed that metamorphism could only
very rarely result in granite. This latter was supposed to represent
an intrusion into the crust of magma which had gone through
changes on the way to the surface.

Recently, geologists, such as Cailleux or Bucher, have re-
examined these traditional concepts. In their view, granite repre-
sents the ultimate end of metamorphism. The mysterious granite
which takes the place of sediments would not have driven them
out, only "digested" them.

In the light of this new concept, which has been accepted by
most authorities, the life of the rocks appears as follows. The
rock is broken up on the surface by the sun's energy and becomes
sediment. The products of erosion are thrust down progressively
into the bowels of the earth and will be able to reach or pass the
moho. Under the influence of pressure, heat, and, probably,
chemical phenomena occurring on contact with the magma, the
sediments are "recooked" and, after undergoing processes still
unexplained, finally reform granite. The working of the earth will then lift this granite to the base of the mountains, for example, and it will eventually reach the surface where it will again be subjected to the influence of solar erosion, which will break it up. Caught between the contrary forces of solar energy which supports the principal agents of erosion, and the profound dynamism of the globe which regenerates the rock, the mineral participates in an endless cycle of death and rebirth.

Obviously this is a theoretical outline, giving only a crudely simplified picture of very complex geological phenomena. In this rocklife the granite would represent a state of equilibrium, a royal state of the mineral kingdom, the antithesis of the sedimentary state. Granitization therefore constitutes one of the principal activities of the earth-organism; in particular, it is intimately linked to the formation of mountains. Indeed, starting with primary sedimentary and volcanic matter, the earth erects mountains, the main parts of which, core and underground roots, are granite. All orogenesis is therefore accompanied by intense granitization.

This digression on mineral alchemy brings us back to our problem of the rising of the mountains. The granitization which accompanies the formation of mountainous massifs may be accompanied by an increase in volume of the substances.

This hypothesis has been maintained by the geologist R. Perrin. He has succeeded in obtaining confirmation of it by changing a silicious sand (a sediment) into orthose feldspath (one of the components of granite). The operation was accompanied by an increase in volume of 55 per cent in the substances. It is therefore not impossible that granitization makes the newborn mountains “swell”, just as leaven puffs up dough.

The American geologist V. Saull is of the opinion that the rocks absorb huge quantities of solar energy in the course of sedimentation. This heat is then released into the sedimentary series, melting the substances deep down. Thus the base of this accumulation of sediments, which will become mountain, acquires a plasticity which promotes its deformation and creasing.

The new rocks which would spring from this fusion would be lighter—therefore more voluminous—than the original sediments. This would explain the expansion of the substances resulting in the
rising of the geosynclinals where the sedimentary mass is heaped up. The mountains would be an extra present from the sun.

Our search for the agent of orogenesis directs us to a whole list of possible culprits. There is enough to be overwhelmed, but not satisfied. We can state almost certainly that none of these forces carries out all the work by itself. Horizontal forces compressing the active zone, vertical efforts raising these masses in hydrostatic disequilibrium, "swelling" of substances in the course of chemical reactions, all these agents of orogenesis participate in common in the rise of mountain chains. As to establishing the responsibility and merits of each, that is another matter, which will not be able to be judged for many years.

THE LONG MOUNTAIN

A chain of mountains over 37,000 miles long exists on our earth, and we have only really known it for a few years. Far from accusing the cartographers of culpable negligence, we must admire the work of scientists who have succeeded in discovering, under thousands of feet of water, the longest mountain in the world. This endless mountain in fact runs the whole length of the ocean beds, showing a certain preference for median regions. The system originates in the Arctic, off the mouth of the Lena, grazes the North Pole, cuts Iceland and crosses the whole Atlantic from north to south, strictly following the middle of the basin. It turns round South Africa and separates in two in the Indian Ocean, at the latitude of Madagascar. One branch heads northwest and touches the continent in the area of Aden. There, it is connected to the Rift Valley, cutting Africa in two, following a depression which starts from Palestine and ends up in the southeastern part of the continent. The second branch follows its route eastward, passes under Australia, shoots an extension toward New Zealand, while continuing to girdle the Pacific by the the extreme south. It finally moves back to the north and rejoins the American coast at the latitude of Mexico where it follows the coast north, uniting then with the continental system. Just like the latter, this system presents specific characteristics which make it a unique geological phenomenon.
Here the fracture is not made up of a succession of arcs, but is continued all of a piece as it follows the middle of ocean basins in the Atlantic and Indian Oceans. All along its 37,000 miles the system seems to present the same aspect. For example, if the Atlantic basin were dried up, we would see in the centre a double chain of mountains many thousand feet high. The two ridges are parallel, separated by a deep valley. The structure, which can reach a width of 1,200 miles, is purely volcanic; neither granite nor sediments are found there. Lava flows progressively to reinforce the massif, but the earthquakes which accompany this activity are never deep. Inversely to the circumcontinental trenches, the flow of heat here is distinctly excessive, from two to eight times above normal, according to Professor Bullard.

The two systems of continental and oceanic fractures are entirely different and even show opposite characteristics on many points. Does not this opposition imply a certain complementariness? We shall consider this presently. We should also note an extremely characteristic structure of the Atlantic basin: the volcanoes are not restricted to the median zone; they are found equally in the two lateral basins, but in these regions they are generally no longer active. It seems that their dormancy is of longer standing the farther they are from the active middle zone.

The central chain is composed of rocks from the deep interior (basalts and peridotites) of which the crystallization—therefore the rise to the surface—is relatively recent, on the order of two million years. As we approach the coasts we find substances whose rise to the surface appears to have occurred much longer ago.

A last peculiarity about the ocean beds is that they are crossed by long rectilinear and often perpendicular faults, at the coasts and in the mountainous underwater system. Very little information exists as yet about these newly discovered fissures, but it had already been established that they are accompanied by horizontal displacements of the earth's crust.

The revelation of this phenomenon is a marvellous technical feat. Researchers at Scripps had discovered such a fault perpendicular to the Californian coast. How could we know whether the two lips of the fault had pressed against one another? At first sight the thing appeared impossible. Is hard enough to reveal such
movements on solid ground. It seemed pure folly to try, with two miles of water separating the observers from the terrain. In spite of the difficulties, scientists succeeded. To reach their objectives they dragged a magnetometer over the ocean beds on both sides of the fault. In this way they were able to record the magnetic irregularities of the rocks on each side. If the two sides of the fracture had always been face to face, the anomalies would have corresponded from one to the other. In fact a difference was observed between the two lips which betrayed an irregularity of one block in relation to the other of more than six hundred miles. Do all the faults discovered, notably on the floor of the Pacific, correspond to such displacements? It is much too early to say, and the observations which have been made need confirmation. Oceanography requires highly specialized personnel and equipment, and in view of its vast field of research it has still only very inadequate means available. It must be given time to pursue the exploration of the hidden face of the earth. Its first discoveries already show, however, that the explanation of the physiology of the earth must be sought on a planetary scale, by bringing to light great geological systems, and that, in this work, underwater exploration will be extremely important from now on. Everywhere in the world geophysicists are impatiently awaiting the results of oceanographic campaigns which are currently in progress. They need these observations to understand the earth. The study of only those lands which lie above water gives a completely false idea of the planet.

We are waiting for many other revelations from oceanographic campaigns, in particular the solution of one of the most irritating mysteries of the earth: the fate of marine sediments. The cycle of erosion and metamorphism does not entirely explain the fate of the mineral kingdom on the earth's surface. Great quantities of substances are, in fact, deposited in the sea. Tiny alluvial particles carried away by the ocean currents, volcanic ash, meteoric dust, organic waste, etc., fall very slowly on to the ocean beds, covering them with a fairly uniform carpet of sediments.

The rate of these deposits has been calculated. It is about three feet for a hundred thousand years. That gives a layer three miles
thick for the five hundred million years that have elapsed since the Cambrian era. The earth's crust could be five to ten times older.

What do we actually observe? It has not been possible to explore the sea beds except by indirect methods based on the behaviour of waves at different levels. Therefore we know only certain physical properties of the substances found there.

Indirect studies show that the ocean bottoms are composed of three superimposed layers. The first is made up of movable sediments and has a thickness no more than a few hundred yards. The second possesses a greater rigidity corresponding well with basalt. Its thickness is established at around one and a quarter miles. Lastly, a third level continues as far as the moho and seems formed of very heavy and very basic basalt. In all this, there is no trace of the three miles of sediments, the minimal required by calculation. Ninety per cent of the sediments are missing.

It is hoped today that the mechanism of the “currents of turbidity” will give the key to the puzzle, which could clear up a phenomenon unexplained for twenty years. On November 18, 1929, a violent shock shook the bed of the Atlantic off Canada. Telegraph companies stated that six underwater cables sunk in the neighbourhood of the epicentre had snapped at the time of the earthquake. There is nothing very unusual about this. More unusual was the breaking, in the thirteen hours which followed, of six other cables far away from the area. Furthermore, those carrying out the repairs observed that these six cables had not been broken abruptly, but seemed to have been gradually severed, to the point of breaking, by a gigantic file.

An explanation was offered in 1952 by the oceanographers of Columbia (B.C.) University, Heezen and Ewing. To understand this new geological phenomenon, it is necessary to know that the ocean basins do not begin immediately at the shore. In fact the continental bases extend several hundred miles out, forming the continental shelf, the shallowest zone of the sea; next, the depth of the bottom sharply increases from hundreds to thousands of feet. The continental sediments are deposited on the continental shelf. When an earthquake shakes these areas, masses of movable sediments are set in motion; when they reach the very edge of the shelf, they form veritable avalanches of mud which hurl them
down to the abysses. Carried on by its impetus, the muddy mass could continue to advance on the ocean bottoms, over hundreds of miles, forming huge mud flows improperly called “currents of turbidity”. These currents may attain a speed of 50 miles per hour. One of these currents could have been caused by the earthquake of November 18, 1929. As it passed over the cables the mass of mud would have rasped them and cut them in two. But this is only a theory.

These still unexplored three-fourths of the earth have decidedly much more to tell us. With the upper mantle, the ocean basins from now on constitute the two main fields of inquiry in earth sciences. Phenomena occur there, totally unsuspected before the war, but about which we still know much too little to claim that we understand our planet. We must grant science ten or twenty years’ respite (that is, hard work) to produce records that will permit us to make a solidly supported attempt at a synthesis.
17 Terrestrial Magnetism

Why does the compass needle always point to the north, that is, toward the Pole Star? When the phenomenon became known in Europe—it had been utilized for a long time before in China—it was thought that all the iron on the surface of the earth had fallen from the Pole Star. It seemed natural that the iron needle should point toward its native land, as though pulled by nostalgia. Since then, however, considerable advances have been made in our knowledge of magnetism and especially of the earth’s magnetic field. It was discovered that the magnetic poles always went in pairs of opposite signs: that poles of the same sign repelled each other and poles of opposite signs attracted each other.

It was then understood that there existed on the surface of the globe a magnetic field which oriented the needle of the compass according to its lines of force. The north pole of this needle was obviously attracted by the earth’s opposite pole which therefore was called the North Pole. Although this nomenclature is perfectly aberrant, the progress of science was not slowed down for so small a thing as the custom of calling the South Pole the North Pole and vice versa.

Why did the earth have a magnetic field? It was natural to think that our globe, so rich in iron, had been magnetized in the beginning and, ever since, was keeping its magnetic properties, just like an ordinary magnet.

Yet it was consequently discovered that metals lost their magnetization above a certain temperature, called the Curie point. This temperature, which is 575° centigrade for iron, must be reached rapidly in the earth. This observation and several others caused the abandonment of the convenient explanation of the terrestrial magnet. Today scientists no longer say that the earth has a magnetic field, but that it produces a magnetic field. It must
behave something like a dynamo-magnet engendering a magnetic field every instant. Once again we have had to abandon the vision of a passive and inert earth for that of a dynamic system, creating by its own life the phenomena that are observed. But these phenomena are so complex and so disconcerting that we are still far from understanding the functioning of the terrestrial electromagnet.

THE CAPRICES OF THE MAGNETIC FIELD

The least observation of the earth’s magnetic field shows that it suffers from a sickly instability. The phenomenon has been known for a long time, for these variations are of a size and rapidity quite extraordinary for a terrestrial phenomenon. While geological actions operate over millions of years, magnetism shows changes of temperament easily discernible on the human scale. For example, the magnetic poles have travelled some two hundred miles in the course of the last fifty years. We are a long way from the imperceptible motion of the geographical poles.

With variations of such a size the phenomena should be easy to make conspicuous, to observe and hence to explain. As Professor E. Thellier, the foremost French specialist in the field, says: "The earth’s magnetic field, always a somewhat closed character, even to its intimates, has a solid reputation for being complicated and enigmatic."

Indeed, if changes in the earth’s magnetism are easy to observe, they are so numerous, so important, and so varied that it is very difficult to isolate the effects in order to go back to the causes, the latter road remaining, for the moment, irremediably barred.

What are these enigmatic variations in the earth’s magnetic field?

The first follows its course in a visibly smooth rhythm and generally in a direction which has been determined for centuries. It is called “secular variation”. On the other hand the second goes, comes, and supervenes in a cyclical or accidental way without resulting finally in a change in a fixed direction. It is a kind of oscillation about a middle field. From these observations scientists distinguished a fundamental field which evolves according to a
precise plan, and a "residual" magnetism, a capricious and unstable field like the sun itself, which is obviously no mere bystander in the matter.

We therefore have two different, superimposed fields. In a normal period the "residual" field constitutes no more than one per cent of the earth's magnetism. This is why, in the past, it could be forgotten, and the fundamental field, which we have identified thanks to its secular variation, could be called, by approximation, the earth's magnetic field.

To the uninitiated, a compass is a needle that shifts on a horizontal plane. In fact if the needle is allowed to move in a vertical plane, it will point to the ground according to an angle covarying with latitude. If we happened to be above a magnetic pole, the needle would be set at the vertical. This magnetized finger, pointing toward the centre of the earth, clearly indicates the origin of terrestrial magnetism. The terrestrial field originates in the deep interior of the globe.

Everything happens schematically, as though there were at the centre of the globe a straight, very short magnet—physicists call it a dipole—visibly pointed according to the rotation axis of the earth. The lines of force of this field—these are lines on the surface, but surfaces in the atmosphere—seem to gush out of the planet according to wider and wider superposed curves. Our earth is therefore girdled by curved magnetic surfaces arranged concentrically and making their effects felt up to tens of thousands of miles. On the surface of the earth the compass needle points in the direction of the magnetic north pole. The magnetic and geographical poles not being confused, the direction indicated forms a fixed angle, called declination, with the geographical meridian of the place—which itself ends in the geographical pole. To a navigator it is clearly essential to know this angle in order to make corrections. Unfortunately, this angle varies constantly.

The first magnetic measurements were carried out in Paris at the beginning of the sixteenth century; they showed that the compass pointed east of the geographical meridian, making an angle of 7° with it. The deviation to the east increased again during a quarter of a century, then the movement was reversed and, under Louis
XIV, the magnetic and geographical meridians were superposed. The magnetized needle was pointing to the geographical pole. But this situation did not last, and the needle moved off again toward the west. Under Napoleon, it attained the maximum declination to the west, with $22^\circ 30'$. It then turned back toward the east and since then has been approaching the geographical meridian. At the present time it is still in the west, but the angle is no more than a few degrees. If the movement continues normally, the Paris compass will point in the direction of the geographical pole about the year 2,000.

The magnetic poles are therefore great travellers. Tens of miles a year does not frighten them. At the moment the North Pole is over Melville Island, in Arctic Canada. As for the South Pole, it is not in its place, which is in the Antipodes. It has considerably shifted in relation to this theoretical point and runs over the desolate icy stretches of the Antarctic. In their displacements, the magnetic poles do not seem very sure of where they are going. It was claimed that they turned fairly regularly round the geographical poles. In fact, they appear to wander at random in the polar turmoil (of course, in science the appeal to chance is a confession of ignorance).

The magnetic field varies, then, in time—we have still been speaking of only the simplest variations—but it is no more constant in space and shows momentous anomalies from place to place.

It is very difficult to make local measurement of the magnetic field. Numerous disturbing elements, for example high-tension wires, could confuse the charts. Certain local anomalies are connected with the presence of metallic minerals in the ground. The study of the magnetic field therefore plays a part in the techniques of mineral prospecting, beside seismology and gravimetry. But other local distortions are too extensive to come from metalliferous beds. Furthermore, it is observed that, over a sufficiently long period, these anomalies slowly shift to the west, which avoids any confusion with the magnetic presence of minerals, which obviously always stay in the same place.

The problem is even more arduous when it comes to measuring magnetism at sea, for all magnetic phenomena are falsified by the
metallic mass of ships. To get to know the magnetic field above the oceans, it was necessary to use specially constructed non-magnetic ships for these missions. There was a vessel of this kind before the 1914 war, the Carnegie, the hull of which was wooden and the motor bronze. Unfortunately it was destroyed by an explosion in 1929. Recently the Russians launched a new, non-magnetic ship, the Zarya, which will be able to complete the magnetic map of the ocean basins.

The most recent magnetic measurements are due to the observation of particles in the atom. It is known that the protons possess a "spin", i.e. they turn on themselves. As it carried an electric charge, this movement of rotation produces a magnetic field. If a particular force acts on the proton, it reacts like a gyroscope by a movement of precession. This is precisely what happens when the magnetic field of the proton interferes with the terrestrial field. In nuclear magnetometers, hydrogen is naturally utilized so as to have only one proton per atom.

The protons are permanently imprisoned in the field created by an electric current. When the current is cut, the protons are under no influence but that of the terrestrial field. As they adapt to this new situation, they adopt a movement of precession proportional to the intensity of the terrestrial field. With an apparatus of this kind, Dr. Victor Vacquier and the scientists of Scripps Institute of Oceanography discovered the grooving along the faults of the eastern Pacific.

THE EARTH IS LOSING ITS MAGNETISM

The fact that the magnetic field turns around the earth is surprising enough, but there is an even more astounding fact: it seems to disappear completely at times, or even be reversed, the North Pole becoming the South Pole.

Since the start of our era the earth's magnetism has diminished by one-third. A question immediately comes to mind: how can we know?

Certainly the Romans did not observe the variations in the magnetic field, since they did not know it existed; but scientists have discovered a kind of natural archives of the earth which have
made strange revelations. Many substances in the earth’s crust contain crystals of iron oxide, magnetite usually. When the rocks were formed, these crystals behaved like so many little compasses, arranging themselves according to the lines of force of the earth’s magnetic field. Afterward they kept their magnetization. Thus the magnetic field is fossilized in the rock, at the time and place of the rock’s formation. By studying the magnetization and orientation of particles of magnetite, the scientist can discover the characteristics of this field. The rocks keep the memory of the field which has known them from infancy, and specialists can evoke magnetic recollections from stones: this is the principle of palaeomagnetism.

The first studies made by this method were concerned with prehistoric potter’s kilns. Thanks to this technique, the great pioneer of which was E. Thellier, we have learned that the intensity of geomagnetism is constantly decreasing. In the course of the last century it lost 5 per cent of its force, but it seems that the movement may recently have been reversed.

By measuring past magnetism in rocks rather than in pottery, it was possible to go back millions of years earlier. Then scientists discovered something scarcely credible: the inversion of the terrestrial magnetic field. If the magnetic memory of stones is to be believed, the North Pole periodically becomes the South Pole and conversely. The earth also passes through periods of complete annihilation of the magnetic field. These bewildering observations were long doubted, but verifications carried out have convinced scientists.

THE TERRESTRIAL CORE: A DYNAMO

Having examined the strange magnetism of the earth under all its lines of force, it is time to ask: where does this magnetic field come from?

Scientists are almost all in agreement in affirming that it originates in the core and is related to the rotation of the earth, a hypothesis confirmed by the observation that Venus, which rotates very slowly, has no magnetic field.

In all probability the terrestrial core constitutes a ball of very
dense metallic plasma, the rotation of which engenders a magnetic field. Starting from this theory, how can we view the generating mechanism of terrestrial magnetism? All the systems proposed up to now are pure speculation. The physics of plasmas is still too new a science and our information about the earth’s core is too uncertain to give solid bases to these hypotheses. In this field, the research pursued on the magneto-hydrodynamic effect—i.e. on the electromagnetic effects caused by plasma in movement in a magnetic field—will perhaps make it possible to develop a perfectly satisfactory model of the earth-dynamo. But science is not yet at that point.

Professors Elsasser and Bullard envisage the possibility of a primordial magnetic field engendered by currents of matter in the core. These movements could have been created by convection or by chemical or electrolytic reactions. The plasmic mass of the core, turning—as a result of the earth’s rotation—in this primordial magnetic field, could have produced an electric current, itself generating terrestrial magnetism. The system would therefore be maintained by the displacement of matter in the core and by the earth’s rotation. Could not the periodic reversal of currents of matter in the core explain the inversion of the poles?

Professor Runcorn is of the opinion that interactions could exist between the electric currents of the core and of the magmatic mantle, in the manner of those which unite the gear in rotation and the field of the sparking coil in an electric motor. This electromagnetic mantle-core coupling could be disturbed by the activity of the sun, creating the “trigger force” of earthquakes.

AGAIN THE SUN

No matter what may be the authority of the scientists who advance these ideas, it is well to consider that they remain highly hypothetical. We shall therefore hold to this wise conclusion: the origin of the earth’s magnetic field is in relation to the rotation of the plasmic mass of the core.

If this is so, how do we explain the magnetic irregularities, notably the drift to the west and the regional anomalies? The most generally accepted theory envisages a slower rotation of the core
in relation to the whole planet. Is it possible that science has rediscovered Halley’s extravagant visions and his system of terrestrial spheres with variable speeds of rotation? When one considers that the British astronomer had imagined his numerous earths precisely in order to explain the shift of the magnetic field, one cannot help hailing his intuition in spite of his rather unrealistic dreams.

Accordingly, our earth may not turn in one piece, which is natural enough behaviour for a heterogeneous body enclosing plastic layers like the exterior core or the upper mantle. The slower rotation of the core would make it lose one turn in 1,600 years.

As to the source of the regional anomalies in the field, let us look at the mass of solar plasma. We have seen that it is disturbed locally by whirlpools of matter, the spots, causing very strong magnetic anomalies. Is it possible that the earth’s core is a small sun? May one not imagine that in places it is formed of whirlpools of matter, the centre of momentous magnetic anomalies which have repercussions on the surface?

This is the possibility envisaged by Professor Tuzo Wilson. The boiling up of plasma in the core would create regional anomalies in the magnetic field. All these currents, differing from solar phenomena, would be infinitely slow, following pressure. This is why they would appear to human observation as permanent anomalies.

Finally we may believe that the currents of matter which run through the magma are not without magnetic consequences and further contribute to complicating the field on the surface.

Superimposed on this fundamental field, then, is a residual field, i.e. a very weak magnetism born in the atmosphere. The sun’s radiation, as we shall see, has the result of ionizing the air, creating a diffuse atmospheric plasma. The atmosphere being a world of great motion, the displacements of this plasma engender a magnetic field. There is a case of a phenomenon completely subservient to solar temperament. It is therefore a magnetism still more capricious, still more fluctuating than the fundamental field and
one which, in periods of solar crises, unleashes magnetic storms. Whatever the generating mechanism of terrestrial magnetism may be, one may already state that it is active and that, here again, our earth possesses the dynamism of a motor in operation, of an organism in function, and not the passivity of an inert body.
The Continents' Great Adventure

We have seen the earth's crust transformed by vertical movements which forever build and destroy mountains. On a geological time scale it looks like the keyboard of a gigantic piano: here a note is pressed down, there another rises up. But are we quite certain that the physiology of the earth is limited to this rise and fall of parts of its surface? May we not imagine more momentous changes in the face of the earth, changes caused by horizontal as well as vertical movements which would displace all or part of the crust over thousands of miles?

It is no longer a matter of geologists' imagining as much as it is their admitting such a contingency. After research resembling the most unusual police investigations, still more scientists are recognizing the reality of such phenomena. But here, too, we are in the theoretical stage. There are so many theories today that an exhaustive study of them would be impossible. Nevertheless, in recent years certain large outlines have begun to appear, which, if we do not peer too closely at the details, give a significant, if blurred, picture of the great adventure of the continents.

The wandering of lands which have risen to the surface of the planet must have left traces. Unfortunately, the proof of an event becomes blurred in the course of the years. When the latter run into millions, and indeed hundreds of millions, of years, it is presumptuous to attempt a reconstruction of the past. However, by employing imagination, patience, ingenuity, and intelligence, the historians of the earth accomplished this feat.

As tools scientists have discovered the most unexpected recording thermometers. David Ericson suggested using an astonishing
property found in globigerians, tiny animals which abound in the oceans. When they live in water with a temperature above 7.2° centigrade, globigerians roll their shells to the right. When the water is colder the shell develops in the opposite direction.

Urey discovered that in limestone sediments the relation between two isotopes of oxygen, oxygen 16 and oxygen 18, depends on the temperature at which the sedimentation took place. A method of reconstructing past climates has already been developed from this observation.

Sometimes scientists can discover the latitude of a region in the past without referring to climatological data, but by studying the direction of winds. Though nothing is more elusive than the wind, it is possible to find out how it blew millions of years ago. On movable ground, on a sandy stretch, for example, the wind forms dunes, the alignment of which clearly depends on the wind’s direction. Sometimes these dunes become petrified, and the crumbling sand changes to solid rock. By studying the orientation of the solidified dunes, the geologist can discover the direction of winds in ancient times. This direction depends on latitude. Atmospheric circulation is not in the same direction at the equator and in the middle latitudes. One can therefore determine approximately the latitude of the region at the time of the solidification of the dunes.

We said before that earth historians were able to establish the presence of glaciation in the tropics and of tropical vegetation in the polar regions. Recently, Professor N. D. Opdyke, of Salisbury University, systematically regrouped these studies on past climates. Using evidence characteristic of different climates (deposits of salt, bauxite, coral), he mapped their sites in the successive geological periods. In this way he was able to follow the shifting of the climatic zones on the surface of the earth in the course of the last 500 million years.

These observations, made by scientists working independently of one another, cross-check in a very satisfactory way. They seem to indicate that at the dawn of geological times, the North Pole was situated in the middle of the Pacific near Hawaii, and that, ever since, it has been gradually moving to its present position. But one may equally well suppose that 500 million years ago the
whole system of surface lands was much farther south and that the southern hemisphere was then the "terrestrial" hemisphere.

This hypothesis, cautiously advanced by specialists in palaeoclimatology and palaeontology, has just been confirmed by palaeomagnetism.

This technique, which has revealed the strange inversions in terrestrial magnetism, can also give information about past positions of continental masses. Before awakening these magnetic memories, it is proper to point out that we are dealing with very young and delicate techniques, which require a degree of caution. We should note especially that all these results depend on the postulate that the magnetic and geographical poles are never very far away from one another. It is more than likely that this is so, but we cannot be too cautious when we question the enigmatic past of our planet. Moreover, in practice this method can disclose only displacements in latitude. The longitudinal shifts are perceptible to it only if they are accompanied by a rotation of the continental blocks.

THE CONTINENTS TELL OF THEIR TRAVELS

Palaeomagnetic measurements carried out in the last ten years come to the same conclusions as palaeoclimatology and palaeontology. The general drift of surface lands to the north is confirmed.

The magnetization found in rocks shows that France was near the Tropic of Capricorn 500 million years ago and stayed in the equatorial zone for the duration of the Primary Period. In the Carboniferous Period France had a latitude of 5° north. These findings of palaeomagnetism are confirmed by a study of coral fossils found in Paris which indicate a latitude of 2° north for this same period.

If we reconstruct the arrangement of the earth's crust in terms of palaeomagnetism, we find that the coal deposits of the northern hemisphere were in the equatorial or tropical zone in the Carboniferous Period, as postulated by theory. The presumed line of the equator then is strewn with coral fossils, salt deposits, and layers of bauxite, all of which are traces of a very warm climate.

We know of the general movement toward the north, but it is
impossible to say whether we are dealing with an autonomous movement of continental masses or a general shift of the crust. Actually, palaeomagnetism is a little more specific than this. If we examine rocks of the same age on the same continent, they show similar positions in relation to the North Pole at a given period. On the other hand, when we analyse rocks of the same age but from different continents, they reveal very varied positions in relation to the Pole. Since there has never been more than one magnetic North Pole, it must be admitted that the respective position of the continents was not the same in the past.

By studying polar movements, it has been possible to reconstruct, approximately, the strange ballet the continents have danced through the ages.

These movements confirm in their main lines the drift of the continents as put forward half a century ago by the German meteorologist Alfred Wegener. The reconstruction made by Professor S. K. Runcorn of King’s College, Newcastle, by synthesizing the palaeomagnetic studies completed up to this time, indicates that the southern lands, which were once joined together, moved away from one another. Australia seems to have been seized by wanderlust and made a complete revolution round the South Pole in a billion years. The Antarctic occupied a position distinctly farther north before settling at the end of the world. The Indian peninsula, formerly stuck to South Africa, crossed the entire Indian Ocean to hit against the Euro-Siberian block. South America and Africa were once joined and gradually became separated by the whole width of the Atlantic. Finally, Europe was not parted from North America until fairly recently. It is established that the polar positions found on both continents coincide until the Triassic Period (170 million years ago). From then on, they moved farther and farther apart until reaching their present positions.

Palaeomagnetism would therefore tend to confirm the drift of the continents, But what precisely is this theory?

One cannot look at a map of the world without being struck by the extraordinary similarity between the west coast of Africa and the east coast of South America. It is obvious that one could fit into the other.
This observation is so evident that it made an impression on Francis Bacon at the beginning of the seventeenth century. In 1685 a Father Placet published a book in which it was proved that "Before the Flood, America was not separated from the Old World". But the theory did not really take shape until 1912, with Alfred Wegener. This young German meteorologist, a passionate visionary, was the first to attempt a dynamic synthesis of the earth. He succeeded in putting forward his ideas in a clear, approachable manner, and stirred up a lively interest in lay minds—and some reserve among very many specialists. Wegener alleged that in the beginning all lands were grouped in a single continent, the Pangea. In the Secondary Period, this block was broken up and each fragment drifted off. To Wegener the continents were rafts sailing on the magnesium silicate cover of the ocean beds. He conjectured that America was still moving away from Europe. Wegener died in 1930 on an expedition in Greenland aimed at taking geodetic measurements to verify this movement.

In the elaboration of his theory Wegener was reproached for having pushed hypothesis too far, daring to advance ideas quickly contradicted by examination of the facts. Carried away by his first intuition, he claimed to have the explanation for everything. The Andes and the Rockies were the result of the braking in the forward movement of the American continent. The Deccan peninsula once stretched as far as Africa; its drifting away had caused the crushing of immense strips of land, which crumpled and formed the Himalayas, and so on.

His opponents did not fail to amass all the contrary facts possible, and his theory, contradicted in detail, was discredited. "It is the dream of a great poet", wrote Professor Termier, who found Wegener's idea "gripping yet inapprehensible". Dream or not, the fact nevertheless remained that, as Du Toit, a South African geologist, remarked, "Our documentation on terrestrial life is in disaccord with the present distribution of the continents".

After the war the first disclosures of palaeomagnetism began to cause doubt among the sceptics. In 1950 the British Association for the Advancement of Science organized a kind of referendum among its members for or against Wegener's ideas. The vote was divided equally: 50 per cent supporting, 50 per cent opposed. If the same vote
were held today, we could be sure that a majority would stand out in favour of the theory advocating the transference of continents.

The theory of continental transference supposes that the continents were joined together in the Primary Period. If the postulate is admitted, there is only one way, with the exception of some variables, of reconstructing the primitive continental block. This is to form a supercontinent in the southern hemisphere comprising South America, Africa, Madagascar, Antarctica, India, Australia, and, higher up, the Arabian Peninsula, not yet separate from the African massif. Geologists have long envisaged the existence of such a continent, which Suess called "The continent of Gondwana", from the name of a region in India. But to Suess, who believed in the cooling of the earth, this continent had been broken up by the collapse of hypothetical "intercontinental bridges".

It was a strange idea to invent bridges between the continents. Indeed, palaeontology had driven geophysicists to such an hypothesis because the Primary fossils showed such a similarity for the continents of the southern hemisphere that one was obliged to suppose such a means of communication between them.

Pollen carried by the wind and animals drifting over the ocean are quite improbable explanations. Life does not seem to cross oceans so easily. Australia, for example, isolated for hundreds of millions of years, has seen its fauna evolve in a quite original way, by the expansion of the marsupials, while everywhere else mammals became the dominant species. It is therefore reasonable enough to believe that similarities carried on in the evolution of life supposed communication between lands.

In 1964 George Meyers, an ichthyologist at Stanford University, pointed out that the similarities between the fresh-water fish of the different continents was a very strong presumption in favour of continental drift. The ocean is an even more insurmountable barrier for fresh-water fish than for land animals.¹

¹We have not yet established what makes European eels undertake a journey of 1,800 miles in the Atlantic to lay their eggs in the Sargasso Sea. Suppose that the Atlantic was only a small sea in the past. The journey to the Sargasso Sea would have been fairly short. Then the distance widened, at the rate of a few centimetres a year. The eels did not realize this, and today they are still obliged to cross the entire ocean, caught in the trap of continental drift.
These striking palaeontological similarities are reinforced by geology. The rocks are in complete agreement with the Gondwana theory. We mentioned the similarity in the outline of the Atlantic coasts, but we should also note that all the areas to be replaced in Gondwana show excellent geological concordance. South Africa, South America, Madagascar, India, and Australia are continental shields formed well before the Cambrian Period. So geology has no objections to the theory that they were part of a puzzle assembled in the Primary Period. More surprising still, if the Old and New Worlds were once joined, the physical accidents (wrinkles, faults, etc.) should fit from one side of the Atlantic to the other like the designs on both sides of a rip in a piece of cloth. This is exactly what we see in the two hemispheres. Du Toit noticed that in the different parts of the Gondwana, traces were found of a very ancient geosynclinal. Respecting the present arrangement of the continents, if we try, to join these segments (South America a little below Buenos Aires, the tip of Africa, western Antarctica and eastern Australia), we obtain a line quite incompatible with a common geological origin. On the other hand, if we put the different pieces of Gondwana back in place, we notice that the fragments are reconciled from one continent to the other in the reconstructed system, forming a geosynclinal, to which Du Toit gave the same “Samfrau” (abbreviation of South America, Africa, and Australia).

The same agreement was established between the Great Glen fault in Scotland and the Cabot fault in North America; they fit when the two continents are brought together.

Unfortunately, one piece of this dismembered Gondwana remained hopelessly silent. No one could say what the Antarctic was beneath its carapace of ice or whether it would take its place in the structure. Although the exploration of the ice continent has only just begun, its answer to scientists’ questions is already known: the Antarctic is indeed part of the family, a piece of Gondwana.

In a recent study two geologists from the University of Ohio, George A. Doumani and William E. Long, reconstructed the history of the Antarctic, making use of their own observations and those of other explorers. The oldest traces of life found under the
ice are those of the Archaeocyathides, marine organisms akin to corals dating back more than a billion years. Thus, in the dawn of geological times, the continent was not situated in the polar regions, but enjoyed a warm climate.

This deduction was confirmed by observations made in the subsequent geological layers where fossils were brought to light indicating a warm climate and flora and fauna specific to all areas of Gondwana from South America to Australia.

In the Permian Period (215 million years ago), the same flora, Glossopteris, is found throughout Gondwana. These tree ferns are unique in having their reproductive structures coming out of the middle of the leaf. Glossopteris multiply in the southern hemisphere, which seems to have had a very undiversified flora at this period. In a way they are the plant emblem of Gondwana.

In the same period, a totally different and extremely varied flora developed in the northern hemisphere. Only two specimens of Glossopteris have been found above the equator. The geological layers are likewise in accord for all southern lands, including the between the flora, fauna, and geology of lands in Godwana. In the Secondary, according to supporters of continental drift, Gondwana was broken up. In the Tertiary Period each fragment drifted on its own. If this was so, the agreement should cease from the Secondary Era. Doumani and Long hold that “In the middle of the Tertiary Period the southern fauna shows considerable isolation. Elsewhere in the world, mammals have already become the dominant terrestrial animals, but there is no trace of such evolution in the Antarctic”. This is the dossier on Gondwana. It undoubtedly gives justification for pushing the continental drift theory further.

Wegener had conjectured that America had drifted west, crossing the Atlantic like a fabulous raft. The presence of the Atlantic Dorsal makes a journey of this kind quite impossible. We know that its composition is entirely different from that of the continents and therefore cannot have been formed by continental sections left behind by the American mass on its way west. But if this underwater chain rises like an insurmountable obstacle to a
"crossing" of the Atlantic by America, may it not constitute a solid presumption in favour of another drift?

Suppose that America did not leave Africa to respond to the "call of the west" but that both continents gradually moved away from each other. One could reasonably believe that the Atlantic Dorsal gave body to the scar caused by the separation of the continents. This would explain its having exactly the same shape as the shores of both continents.

The implication of such a theory, supported by many Anglo-Saxon geophysicists, is that, the same causes producing the same effects, a like structure is found under the Indian Ocean. But in this case the movements of the continental bases were much more complex. India went up to the northeast, Australia moved off to the east, and the Antarctic came down to the southeast. If these movements developed according to the same process as the America-Africa separation, the bottom of the Indian Ocean must be checkered with scars. In this very connection, the international oceanographic mission at present exploring this ocean under the aegis of UNESCO seems to be turning up traces of such fractures.

Oceanography therefore puts forward no invalidating argument against continental drift by reciprocal separation. We must consider, next, what mechanism could account for a phenomenon of this kind.

The progressive formation of the Atlantic and Indian basins supposes that some parts are more recent than others. Bruce C. Heezen, an oceanologist, examining the Atlantic established that the median zone is the latest, going back probably to the Tertiary Period. Samples of basalt were dated by the argon-potassium method employed by G. Erickson. They disclosed an age of 20 million years.

To explain these different observations (the disposition of active volcanoes, the flow of internal heat, etc.), English and American geophysicists have advanced hypotheses which may be summarized as follows. Vertical to the system of ocean fractures a magmatic current rises, carrying overheated matter. When the magma strikes against the solid crust, it flows horizontally on both sides. Only a tiny part passes through the fracture. Two huge streams of matter therefore flow perpendicularly to the Atlantic
Dorsal (to the west and to the east in the Atlantic) beneath the ocean beds. These moving subterranean masses constantly separate the continental blocks which border the ocean basin.

How can the ocean floors support an extension like this? Scientists believe that the crust does not stretch, but that it follows the movement like a rolling carpet, renewing itself constantly in the median zone. The mantle keeps disgorging basalt by the central fracture (the phenomena of fusion and crystallization change magma into basalt). The mobility of the sea beds draws this new matter outside the active zone, forever lengthening the ocean bottoms by this acquisition of matter from the deep interior. Thus, although the ocean basins grow wider, the crust which carpets them does not become stretched out and preserves its thickness. It would seem that this rolling carpet glides under the continents. When the magma cools down at the end of its long journey under the crust, it goes back down toward the interior, where it is reheated. The hot current originating in mid-Atlantic glides as far as the west coast of the American continent, where the cold descending current forms, which evidently corresponds to the system of continental fractures. Thus the opposition and the complementarity of the two planetary systems are explained: one corresponds to a warm ascending current, the other to a cold descending current.

The descending current causes a phenomenon of suction which draws the basaltic carpet toward the bottom. This is how the ocean trenches, which border the continents, are formed.

Huge slabs of solidified basalt will therefore sink into the mantle, where they will melt in contact with hotter matter. But this fusion is very gradual. Enormous slabs of solid rock could be situated at depths (the asthenosphere, about 90 miles down) where seismic registering indicates a very plastic state of matter. The rupture of these rigid masses would explain earthquakes which the plasticity of matter makes incomprehensible in the upper layers of the mantle.

On the other hand, continents are not drawn down like the basaltic ocean carpets. Indeed, the law of the flotation of bodies does not permit a body of low density to sink in a heavier fluid; cork will not sink in water. In the case of basalt, the variation of
density with the magma is slight enough for the mechanical force exerted by the descending currents to draw it down. The blocks of granite are too light to sink. So they remain on the surface, but, by being pushed forward, they at length fold up and form the mountains.

Constant pressure is exerted on the ocean basins. For example, South America has a tendency to encroach on the Pacific. This pressure would explain the gigantic fractures which run under the continents. The continental mass overlaps the ocean bottom.

The advantage of this hypothesis is that it explain the peculiarities of the two systems of planetary fractures. It is quite normal, for example, that the flow of heat should be very high above the hot ascending currents, i.e. along the ocean systems of fractures, and rather low in the ocean trenches perpendicular to the cold currents. In these zones a suction phenomenon causes the negative anomalies in weight. In a former era it could have prevented isostatic readjustments from operating.

Volcanoes would form above the hot currents, i.e. in the middle of the oceans. But the mobility of the sea beds would eventually drive them away from the active median zone. After several million years, they would be far from the ascending current which nourished them. They would then stop being active. This phenomenon would explain the dormancy of the volcanoes in the lateral basins of the Atlantic. Extending this hypothesis, R. S. Dietz, an American, conjectures that the ocean bed is only the upper part of the mantle, scarcely differentiated from it. Only the continents form the earth’s crust, properly speaking. Under the oceans the upper layers of the mantle would simply be worked by a phenomenon of hydratation leading to the “serpentinization” of the magma.

According to this theory the streams of magma do not flow under the ocean crust but are the crust itself in a state of constant displacement. So the bed of the Atlantic should be represented as two huge whirlpools of magma, with substantially the form of two cylinders in a north-south line turning in opposite directions. The terms “whirlpool” and “rolling carpet” must not hide the fact that we are dealing with geological phenomena, therefore
infinitely slow processes, with a speed of a few inches per year. The earth can do anything except hurry.

Synthesizing the various theories, Professor Tuzo Wilson recently put forward a modern version of continental drift which expresses rather well the present tendencies of geophysics.

In his reconstruction, Africa and America are joined in such a way that their line of coincidence follows the Atlantic Dorsal. Arabia is linked to this block; the Alpine crease goes the whole distance from Spain to Malaysia. Eastern Siberia is separated from the Euro-Siberian block and is connected to the American block.

As to why this block was broken up in the Secondary Period, Runcorn, taking up Urey’s ideas on the formation of the earth, thinks that their on core was composed little by little by differentiation in a planet which was formed “cold”. There was therefore a progressive growth of the core and a correlative diminution of the rocky mantle. Theoretical calculations show that the convection currents should agitate the whole mantle and that the whirlpools will be wider as the mantle is thicker. Billions of years ago, the core being infinitely less voluminous than at the present, the currents of matter ran over practically all the globe and there could not have been more than two whirlpools for the whole earth. Then, as the iron accumulated in the centre, the mantle progressively diminished in thickness. New systems of currents then came into being, with four, six, then eight whirlpools. Probably the first great stream of magma, which carried matter from one pole to the other, eventually caused the formation of relief vertical to the hot ascending current, most likely in the southern polar regions. Thus the first continent appeared. Later the division in two of the original magmatic current fractured this single block. Then, as the whirlpools of matter multiplied, new fissures were made in the Pangea until the primitive shields of our present-day continents were isolated.

The primitive super-continent was therefore broken up above the hot ascending currents. This is exactly what is happening in Africa at the moment.

Many scientists believe that the Rift Valley—the depression which starts in Palestine and runs as far as the Mozambique canal—marks the site of a hot current which is breaking Africa and the
Middle East in two. In a few million years it is probable that an ocean basin, or at least an arm of the sea, will separate all of east Africa (Somalia, Libya, Ethiopia, Kenya, Tanganyika and Mozambique) from the rest of the continental mass. This hypothesis rests on very convincing geological observations. We know that the north-south depression, the Rift Valley, which runs to the east of Africa, fits in with the system of ocean fracture in the Gulf of Aden. The structure of both systems is exactly the same: we find the central valley with two chains of parallel mountains, volcanism, etc. Samples of deep rock have also been recovered from the bed of the Red Sea giving proof of fissures in the crust and magmatic discharges.

Lastly it has been established that the African ditch is constantly growing wider at a rate of inches per year, corresponding with the supposed mechanisms. It would therefore fit in with the plausible schema that the supercontinent was fragmented in the Secondary Period.

It should be remembered that this is only one outline among many others. To date, the latest version of continental drift was put forward in May 1964 by a Soviet scientist, V. Vassiliev. According to his “bipolar diagram”, the primitive continents were formed as polar mounds in the north and south. The mechanical effects of the earth’s rotation made them break up and drift toward the equator. In the Tertiary Period the blocks coming from the north and south collided and caused the Alpine crease.

The breaking up of the terrestrial crust could also be explained by a dilation of the globe, either after it became heated or after a diminution of the gravitational constant. This theory seems to be gaining ground at the present time. As seen by scientists like Heezen, Dicke, and Tuzo Wilson, it is not necessarily incompatible with the mechanism of convection currents.

The drift of the continents was latitudinal as well as longitudinal. Convection currents or the expansion of the earth could have caused the lands to move north. Many scientists doubt this and look to entirely different mechanisms for the explanation of these phenomena.

Some authorities have conjectured that the crust could be sliding in one piece over the mantle. The Chinese oceanographer
Ting Ying H. Ma based his studies essentially on observation of coral fossils. He reached the conclusion that, if continental drift really took place, it was accompanied by a general sliding of the terrestrial crust. The transference of continents would essentially explain the longitudinal movements, and the drift of the crust would explain latitudinal changes.

What force could have set the whole crust in motion? A very attractive theory was advanced by Charles Hapgood, an American. Taking up Brown’s cataclysmic visions, he thinks that the eccentricity of the polar dome may have serious consequences. But he absolutely excludes the possibility of the planet going seesaw. On the other hand, he affirms that this force would be sufficient to make the earth’s crust slide by fits and starts.

A glacier can only form on solid ground. Hapgood points out that only 4 per cent of the continents have land above sea level at their antipodes. As a result, the glacial ice-caps are formed only in one hemisphere at a time. These glaciers grow so rapidly that there is no time for isostatic compensation. They therefore create disequilibrium which is accentuated until it starts the whole crust moving. Carried outside the polar regions, the glacial icecap begins to melt, while another forms. This phenomenon would introduce into the history of the earth a cyclic catastrophism of which the periodicity would be in the order of forty thousand years. The jolting movements of the crust are responsible for the formation of mountains and underwater faults, for the crust is subjected, in its displacements, to wrinkling, or extension due to the swelling of the equator.

At the moment Hapgood is a declared anti-Wegenerian. He believes that the continental blocks could not have been displaced autonomously. But no one is prohibited from thinking that in the future his ideas will be integrated in a more complex synthesis.

Other mechanisms have also been envisaged. Pauly reckons that the action of the tides would be sufficient to shift the earth’s crust imperceptibly. Gold believes in the possibility of a constant imperceptible seesaw motion of the planet put in disequilibrium by the appearance of new relief.

We have difficulty in choosing from among this wealth of hypotheses, but in science the accumulation of hypotheses is
generally a confession of ignorance. This is especially true of earth-science.

**EVERYTHING IS NOT SO SIMPLE**

We must come back to this affidavit of ignorance. It is always a dangerous game to yield to hypotheses, to accept them as certainty. Suddenly the facts become accomplices and seem quite prudently to set themselves in order, to give a false impression of certainty. More than any other, the brief for continental drift presents this danger. Before the war it was pleaded with perhaps untimely enthusiasm. Recent confirmation should not let us forget the weaknesses of a theory which in essence remains hypothetical.

It is not yet known how this hypothesis can be reconciled with that of the continuous growth of continents and mountains, which geologists are viewing more and more favourably.

Is the strong interdependence which unites the crust and the upper mantle compatible with the transference of continents? It seems quite impossible to the Russian scientist Belousov, the current president of the International Geophysical and Geodetic Union. To reconcile the two phenomena, Bernal conjectured that these currents were produced only in the lower mantle at a depth of 430 miles.

The convection currents leave a number of questions unanswered. Why are they formed in one place rather than another? Do these streams of matter move perpetually or by jerks? Do the whirlpools shift? Are some immobilized, while others are created? are these currents not rather caused by isostasis?

Vertical movements of the earth’s crust have been established, not easily compatible with the transference of continents. Thus, the Colorado Plateau has risen 4,900 feet since the Tertiary Period, without any wrinkling or sedimentary accumulation. Ewing, an oceanographer, discovered that a whole section of the American continent belonging to the Appalachian crease had sunk and was lying under water 10,500 feet down. These facts cannot be explained at present in terms of continental drift.

In this study we have most particularly stressed horizontal
movements, because it seems that science is moving in this direction. The most recent discoveries are in favour of continental drift, but this certainly does not mean that everything will not be called in question tomorrow. There is an undisputable advantage to all these hypotheses: we can never again consider our planet as it was considered decades ago. Today's theories will perhaps be abandoned tomorrow, but it is highly probable that this will be because of further development in the evolution of our knowledge of the earth and not of a return to yesterday's ideas.

THE DRIFT TODAY

We must answer one more question: are the continents moving at the present time? The answer is certainly in the affirmative. It was formerly thought that the earth passed through alternate periods of calm and activity. In the Tertiary Period the globe had built the Alpine crease: since then it had been resting. Today this idea is very largely abandoned. Geological phenomena continue permanently. There is therefore every reason for believing that, if the continents moved in the past, they are continuing their movement in our time.

An international commission was created to try to establish whether the Old and New Worlds were still moving apart. For fifteen years it compared observations made by scientists from all over the world. It finally settled on a come-and-go movement of 65 feet between the two shores of the Atlantic. This beat followed a periodicity of eleven years. For five and one-half years the distance increased and for five and one-half it diminished. Eleven years is the solar cycle, which could not be mere coincidence. The globe therefore pulsates by the action of the sun. However, these observations remain subject to caution, for they are reaching the extreme limit of instrumental possibilities. Thanks to geodetic satellites, we shall have confirmation or invalidation of this phenomenon in the years to come.

Finally, eventual movements can be made plain along the faults. We have pointed out the grooves along the five great Pacific faults. It seems that numerous faults of the same type exist in the Atlantic. They are perpendicular to the middle chain and corres-
pond likewise to displacements on both sides of the fracture. The whole chain appears to be thus cut up in sections spaced in proportion to one another. This phenomenon is difficult to reconcile with continental drift. An America-Europe separation should cause north-south faults like the central fracture, and not east-west faults.

One branch of the ocean system of fractures seems especially active, namely the African Rift Valley. It is established that the ocean ditch is growing wider at the rate of 1.4 inches per year. It would be the same for the fault which cuts Iceland. But there is no proof that the 37,000 miles of ocean fracture are also active.

Along the system of continental fractures, coercion is generally exerted perpendicularly to the line of fracture, and in opposition to it. This double opposing thrust is finally expressed by a lifting movement and therefore by vertical rather than horizontal movements. But this does not seem to be the situation along the American Pacific coast. In this region the San Andreas fault has been the subject of particular study. There seems to be a southward movement on the continental side and a northward movement of the ocean side. Geologists have found displacements of several tens of miles. The extraordinary thing is that this movement not only is continuing in our time, but seems even to be accelerating. Indisputable geodetic measurements prove that both sides of the fault are shifting in opposite directions at a rate of two inches a year. This is a very rapid rate, since it represents 3,100 miles since the Cretaceous Period.

California is not the only region where such dynamism is observed. Grooves 300 miles long were pointed out along the New Zealand faults; Wellman, a geologist who studied this fault, thinks that its rate of movement has been accelerating since the Tertiary Period.

From the whole body of these observations, two geologists, Hugo Benioff and Saint-Amand, working independently, came to the conclusion that the Pacific basin was the seat of a huge planetary round-about. The ocean beds turn counter-clockwise. This is only a geological “impression”, but one formulated by scientists and resting on solid observations. As to understanding
the mechanism of this whirlpool, no one has yet ventured to put forward the slightest hypothesis.

Is it credible that our calm and solid earth should be a world in such transformation? It seems quite improbable to the uninitiated that mountains are born and continents are moving beneath our eyes. The fact is that the earth dilutes its action in time. Its rhythm has no common measure with ours; but science has found the means to surmount that barrier. The miraculous weapon against the earth’s infinite slowness is precise observation. Thanks to the amazing exactness of devices like satellites, lasers, etc., our planet will soon be no longer able to conceal its secret movements from us.
19/ Between Us and the Sun: the Atmosphere

The atmosphere is substantially part of the earth’s make-up, from the double-point of view of its origin and its function. In all likelihood the atmospheric matter was exhaled by the earth in its infancy after the escape of a first gaseous envelope. Since that time the interdependence between the globe and the atmosphere has never stopped. All atmospheric elements periodically return to the earth: nitrogen every 100 million years, oxygen every 2,000 years, and carbon dioxide every 35 years. We must remember also that it is the work of the biosphere that makes it possible for the atmosphere to draw on free oxygen in such quantity.

But the integration of the atmosphere into the earth-organism results essentially from the function that it fulfills there. Our planet bathes in the solar presence. The torrent of energy is too brutal for our globe and the layer of life that it carries. Luckily, the gaseous envelope is there to filter these powerful gifts from our star. In fulfilling this function, it has acquired its own composition and dynamic structure: it has become the earth’s atmosphere.

Our atmosphere must be studied in relation to this general work of receiving the sun. The problem is not to describe what it is, but what it does... for all we know about it.

This “treatment” of radiation and solar substance happens progressively through the thousands of miles of the atmospheric filter. The atmosphere intercepts the quasi-totality of solar radiation of less than 4,000 Angstroms, that is, X rays and ultraviolet rays, which the biosphere cannot stand. The absorption takes place by the meeting of the waves and the atmospheric molecules. The result of these collisions varies according to the nature of the wave and the grain of matter. But whatever it is, dissociation of the
molecules, ionization, recombination of atoms, etc., it will be expressed, in the last analysis, by the disappearance of the life-killing wave in the mass of the atmosphere.

The absorption of solar radiation occurs in different conditions and at different levels according to the wave length; the very short waves, X rays, are stopped first; ultraviolet rays are intercepted last. The waves of more than 4,000 Angstroms are not absorbed at all; they are the rays of visible light.

The atmosphere is thus composed of a series of superposed filters corresponding to the different wave lengths, the composition of which is created by and for this well-determined function. So the gaseous envelope of the earth is a world of superposed layers just like the terrestrial globe.

But the atmosphere is equally a world in perpetual commotion. At every level its physical properties vary indefinitely. This is why numerical values concerning the atmosphere are always only categories of magnitude.

In this fluctuating world, nevertheless, one constant is observed, the chemical composition of dry air: 21 per cent oxygen, 78 per cent nitrogen. In the low layers—the first fifty miles—this ratio practically never varies. At first sight, this is an astonishing phenomenon, since air is a gaseous mixture and not a chemical compound. But the constant agitation which works upon the huge mass of the atmosphere (one million billion tons of air) quickly reabsorbs any local disequilibrium in its chemical composition.

This unchangeable quality in the air does not extend to all its components. Two of them, water and carbon dioxide, are subject to variations which may have important consequences. However the proportion of these remains very small, in the order of 0.03 per cent for carbonic gas, and from 0.1 per cent to 5 per cent for water vapour.

This gaseous mass is not disturbed evenly around the globe. Atmospheric density observes a geometric diminution in proportion to its height above the earth. Ninety-five per cent of the atmosphere lies within the first twelve miles. Thus, in the ascent which we are now going to undertake, we shall see the air becoming more and more rarefied until it reaches a "density" corresponding to a vacuum emptier than any created in the
laboratory. But this almost "nothing" constitutes a real world, the influence of which constantly makes itself felt on the earth.

**Our Atmosphere: The Troposphere**

The first layer of the atmosphere, that which is in contact with the ground and in which we bathe, is called the troposphere. It is our atmosphere in the usual sense of the term. These first four miles do not act as a filter, since waves harmful to life are intercepted at the higher levels. The troposphere is therefore entirely subject to the influence of the globe. The heat it receives from it varies considerably according to latitude and season, causing constant circulation in the atmosphere. This is the origin of the chief meteorological phenomena, winds, storms, clouds, hurricanes, etc.

The air, heated on contact with the earth's surface, rises and gradually loses its heat. Consequently, the temperature falls proportionately to altitude until it reaches some—60° centigrade. At that point the thermometer stops falling: we come to the tropopause, the upper limit of this first atmospheric layer.

**The Jet Streams**

At this level very strange phenomena occur: jet streams. American pilots had such a bad experience on their first encounter with jet streams that they claim their discovery. However, the Japanese have come very close to proving that they were familiar with them first. The facts are these.

In 1944 a U.S. Air Force B-29 bomber was on a mission to Japan. The weather was good and the plane was flying eventfully over the Pacific when gradually it began to slow down. The pilot gave his engines full power, but to no avail; the plane was not moving. Yet it still kept its altitude of 26,000 feet. Finally the pilot had to drop his bombs over the ocean and turn back without having any idea what had happened.

But the Japanese knew that extremely violent air currents were sometimes formed at very high altitudes and decided to use them against America. They manufactured 9,000 balloons, loaded with incendiary bombs, which a special apparatus would maintain at the
altitude of the jet streams during the flight. Planes were to escort the flotilla to follow its progress toward the United States.

All this was very ingeniously contrived, but when the operation was launched in the spring of 1944 only 10 per cent of the balloons reached the American continent. There they scattered somewhat at random, exploded in flight and fell over the shore or over Mexico. The damage caused to the United States was very limited. The jet streams were willing to stop American bombs from reaching Japan, but they refused to carry Japanese bombs over the United States.

Today jet streams are phenomena well known to scientists. They are extraordinarily violent winds, blowing at speeds of over three hundred miles per hour and circling the earth—from east to west in our hemisphere—at altitudes of 20,000 to 50,000 feet. They blow in median latitudes, that is, in zones where the cold air from the polar regions meets the warm air of the tropics. This meeting causes disequilibrium in the mass of the atmosphere which creates huge air currents.

Ozone: A Trap for Ultraviolet Rays

Above the tropopause is the stratosphere. Beyond the jet stream zone the influence of ground heat weakens enough for the vertical movements of atmospheric masses to cease. The stratosphere is a zone of calm where the temperature is even.

Nevertheless, from twenty miles onward the thermometer starts to rise rapidly: the atmosphere begins to perform its functions as solar filter.

The first atmospheric filter, whose job is to stop ultraviolet rays close to visible light, functions with ozone. The oxygen in ordinary air appears in the form of molecules composed of two atoms, O₂. In the layers above the stratosphere, the ultraviolet rays sometimes succeed in dissociating these molecules. The separated atoms will have a tendency to form families of three with the biatomic molecules. Thus molecules composed of three atoms of oxygen come into being, i.e. O₃. This triatomic oxygen forms a malodorous, toxic, and corrosive gas: ozone.

There is a strong concentration of ozone between 12 and 20
miles up. The dissociation of the molecules of O$_2$ has been effected ultraviolet light of 2,400 Angstroms which, as a result, has been blocked. But the waves between 2,400 and 4,000 continue toward the earth. Although these rays are feeble for ultraviolet light, they are still much too harsh for fragile living organisms. Fortunately, they meet the ozone layer. They separate the molecules of ozone, just as the stronger waves had separated those of O$_2$ and thus the final thrust of deadly rays is stopped and life is protected.

In the course of our climb through the poisonous layers of ozone, we have come to another layer: we have passed from the stratosphere into the mesosphere. Two phenomena mark this frontier: the appearance of turbulence in contrast to the calm of the stratosphere, and, above all, the first traces of ionization.

THE SKY IN THE SERVICE OF RADIO

When Hertz discovered the radio waves that later bore his name, he thought, very logically, that as these waves moved in a straight line and the earth was curved, they could never be used for long-distance communications.

However, in 1901 Marconi tried to establish a radio-electric link between Poldhu, in Cornwall, and St. John, Newfoundland. It had been established, proved, and demonstrated that the experiment would fail. It had the bad manners to succeed.

In six months science was giving the exact explanation: the atmosphere acts like a mirror and reflects radio waves. How is such a phenomenon possible? Radio waves are produced by the rapid oscillation of electrons in an electric field. The speed of the oscillations gives the frequency of the wave; it is generally in the order of a million oscillations per second. When the wave, thus produced, meets a free electron, it transmits this oscillatory movement to it. The electron then starts to vibrate and produces a new wave of the same type going in the opposite direction, the reflected wave. For a wave to be reflected, it must strike an environment containing free electrons. The waves are not reflected indifferently on any reflector. If they are very long they can use a reflector with only a very small electronic density. But radiation of very short wave length requires a mirror rich in electrons.
We now come to the layers of the atmosphere where independent electrons exist. In the lower levels matter is in the ordinary gaseous state, the molecular state. But above thirty miles the biatomic molecules of nitrogen and oxygen contend with extremely powerful electro-magnetic radiation (ultraviolet rays of less than 2,400 Angstroms and X rays). The absorption of this radiation mutilates the grains of matter, and we have molecules that have lost electrons—ionized molecules—or solitary atoms (after the break-up of molecules), or even the remains of atoms. Therefore the conditions are assembled for the atmosphere to perform its function as a radio-electric reflector. The ionization of the atmosphere is evidently not the same in every layer. The upper layers, which receive all electromagnetic radiation and absorb the most powerful waves, are in a more advanced state of atomic disorder than the low layers receiving relatively weak waves. Therefore ionization increases with the height of the layers. The number of free electrons constantly increases while the number of atoms and, a fortiori, of intact molecules decreases.

This progression of ionization does not occur regularly, but by stages. The ionosphere consists of four superposed electrified layers of increasing electronic density.

There is thus a mirror for each wave length. But the shortest radio waves, those between 30 and 65 feet, cannot find a screen with sufficient electronic density in the ionosphere to reflect them. They cross the atmosphere and are lost in the cosmos. So telecommunications cannot be accomplished with waves as short as this. But although it is impossible to use such short waves to communicate with another point on the earth’s surface, if we wish to make contact with the cosmos they are the only waves we can use. Radio contact with satellites is established through this channel.

Not being able to reflect very short radio waves was a great drawback until recently, since these are the waves used by television. But now that Telstar, Relay and other Syncoms are orbiting overhead, the problem is resolved and the atmospheric reflectors, natural and artificial, make a complete scale for all wave lengths.

The first atmospheric mirror lies above the ozone layer, about
37 miles up. Called layer D, it still has very few electrons, in the neighbourhood of one hundred per cubic centimetre. On such a loose electronic screen only the longest radio waves can be reflected. The shorter waves pass through layer D and look for a suitable reflector higher up.

But electromagnetic radiation begins to modify the chemical composition of the air. We see the formation of ionized molecules of nitric oxide, NO+. Air is not quite air any more and is less and less like the gas we breathe.

The temperature, which had risen up to positive values in the ozone layers, starts to fall again. The coldest zone in the atmosphere lies about 60 miles from the earth with temperatures in the order of −80° centigrade. Still climbing, we pass through the world of shooting stars, at between 50 and 75 miles. Fireballs which have safely passed through the higher layers of rarefied air are burned up here.

At 60 miles the atmosphere deploys its second mirror: layer E. This has ten times more electrons and reflects medium waves.

Abruptly, the thermometer goes wild and climbs to staggering temperatures within a few dozen miles (800° centigrade at 93 miles). We are now in the most active zone of the atmospheric filter. The intense absorption of still more powerful electromagnetic radiation causes the rise in temperature. The atmosphere heats up like a running engine.

The temperature denotes a state of excitation in the matter, which begins to radiate heat. But the air is so rarefied at this level that this excitation does not cause a significant calorific discharge. Obviously, this means that this rarefied air does not “burn” in spite of its very high temperature.

This empty space\(^1\) in the upper atmosphere leads into the artificial satellite zone. In the lower layers the density of the air would cause a space vehicle to heat up and slow down rapidly. But above 93 miles transitory satellization becomes possible. This is why the

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\(^1\)To illustrate this “empty space”, suppose that all the charged particles contained in the Van Allen belt do not exceed the weight of a man. When the Americans, by high altitude explosions, caused an artificial radiation belt which damaged three satellites in the area at the same time, all the artificially created electrified particles could not have weighed more than three grams.
cosmonauts have cruised in these regions. Longer flights are made at higher altitudes. In astronautics, 93 miles marks the true limit of the atmosphere, the end of the dense layers which prohibit space travel.

Ionization intensifies with altitude. It reaches a million electrons per cubic centimetre at 186 miles, and two million at 250 miles. This is the region of the F layers (layer F1 and layer F2). The same symbol (F) is given to both layers since they really make up a single region which is divided in two during the day and forms only one layer during the night. These are the most stable atmospheric mirrors.

They are particularly valuable reflectors since layers D and E vanish at night. Layer F2 is always there. The reasons for this nocturnal drowsiness are easy to understand. The electrons produced by solar electromagnetic bombardment are quickly absorbed by the ionized atoms. Therefore the production and destruction of electrons occur simultaneously. But during the night solar radiation stops, and electronic production stops. The electrons, being few in number in the lower ionosphere, are quickly absorbed. The air then loses its ionization, and the radio-electric mirror disappears. On the other hand, in layer F2 the electronic density is such that the mirror can remain an entire night.

Beyond the F zone, the electronic density diminishes as the solar rays do not meet enough atoms to ionize.

THE TOP LAYER

We have now reached the top layer of the atmosphere, the exosphere, which extends from 435 to 3,100 miles. Properly speaking, the atmosphere ends there. Now we find only a few dozen particles per cubic centimetre. This density is much like that of interplanetary space.

The atmosphere here consists of an ionized gas not at all like air. From 186 miles the predominant element is oxygen in the state of isolated atoms. But above 621 miles light gases, hydrogen and helium, appear. It is most natural that light elements rise higher than bodies like oxygen and nitrogen, and from the top of the
atmosphere. We know in fact, that a layer of helium exists between 620 and 1,500 miles, and at higher altitudes a corona of hydrogen extends for thousands of miles.

The presence of this mass of hydrogen may be surprising. In the gaseous state, the molecules are driven faster the lighter the atom. The lightest of all atoms, that of hydrogen, possesses the greatest speed. The speed increases with temperature, and calculation shows that at several thousand miles from the earth hydrogen atoms must attain the speed of satellization. Matter being very rarefied, the atoms can travel great distances without colliding with one another.

In the hydrogen corona the atoms must behave like earth satellites orbiting our planet in all directions. If these micro-satellites gain new acceleration, after a collision or by solar electromagnetic radiation, they will reach the speed of liberation. Then, like interplanetary probes taking off from an orbital platform, they go in the direction of the cosmos.

Thus the hydrogen in the upper atmosphere must constantly be dissipated into the cosmos. This phenomenon continuing for billions of years, how is it that this hydrogen corona still subsists today? It must be that the hydrogen in the atmosphere is constantly renewed.

The source is now known. To the great surprise of astrophysicists, satellites and rockets disclosed the presence of molecules of water in the very high atmosphere. At this altitude the molecules are dissociated by ultraviolet solar rays. The two liberated hydrogen atoms rise up into the corona, then vanish in the cosmos. Thus the earth is constantly losing its water. But the phenomenon is too slow for there to be any danger of our planet’s drying up in the future.

AN UNSTABLE WORLD

There is a danger that this quick crossing of the upper atmosphere may conceal one of its essential characteristics, movement. The upper atmosphere is a changing, fluctuating world. Astrophysicists who “listen” to it never obtain the same values for the
same phenomena. We shall give only a few significant examples of this unhealthy instability.

In 1958 the Sputniks found a density of $3 \times 10^{-17}$ grams per cubic centimetre at 400 miles. Less than two years later Explorer 9 recorded a density ten times higher. In some regions of the globe, layer F\textsubscript{1} disappears in winter. In the neighbourhood of layer E a second ionized layer appears, so evanescent that it is called the sporadic layer E.

The altitude of the ionospheric mirrors is also variable. Layer D rambles between 37 and 62 miles. The rate of ionization varies according to the hour, day, season, rotation, and cycle of the sun, etc.

These changes are not gradual, but abrupt. The ionosphere is agitated by vertical and horizontal currents, or crossed by electrical phenomena, of which we have only a very small idea from the winds and storms with which we are familiar.

The true picture of the upper atmosphere is therefore of a world in turmoil, endlessly throbbing under the breath of the sun.

This perpetual motion turns the ionosphere into an electric dynamo.

Essentially, a dynamo consists of a conduction-coil fixed to a movable armature that turns in the field of a permanent magnet. When the conduction coils move perpendicularly to the lines of magnetic force, an induced current starts to cross them. This is exactly what happens in the ionosphere.

Air in the ordinary molecular state is a very weak conductor. When an electric contact is left in free air, no current passes between the two poles. On the other hand, the ionized layers conduct and behave like the electric wires in a dynamo. The magnetic field is obviously the earth’s. The movement of the conduction coil is supplied by the work of the tides which agitates the electrified layers in the magnetic field. An induced current arises in the ionosphere, essentially in layer E.

The masses set in motion are so considerable that the total intensity of ionospheric currents can reach one million amperes.

Usually a dynamo is coupled with an electric motor which turns the current produced into movement. The structure of the motor is the same as that of the dynamo. In this instance, however, it is
the current that is supplied and the movement that is produced.

This second function is performed by layer F. The current produced in layer E passes into layer F which, working like an electric motor, is then set in motion.

Thus, the ionospheric layers are electrically coupled, and by their opposing and complementary activities they maintain their movement constantly. These electric forces further complicate the working of the diverse phenomena which act upon the atmospheric forces.

**RADIATION BELTS**

When Explorer I was placed in orbit in January 1958, it took a geiger counter into space to measure the intensity of cosmic radiation. It could only record particles of a certain energy. As the atmosphere intercepts cosmic radiation, it was expected that there would be a constant increase in corpuscular density with altitude. Actually, what was observed by Professor Van Allen, the “father” of the Explorer satellites, was very different. Every time the satellite passed the altitude of 621 miles in the equatorial regions, the number of particles registered dropped to zero. Then, when it went back to its perigee, the count rose normally again and indicated a density that agreed fairly well with theoretical calculations. Why were no particles registered above 621 miles?

Instrument failure was at first suspected, but Explorer 3 confirmed the phenomenon (Explorer 2 had been unsuccessful). Only one explanation was possible: the instruments were involved in a mysterious “radiant force” of such intensity that they were saturated and registered nothing.

Explorer 4 and Sputnik 3 confirmed this hypothesis. Above 621 miles there was a corpuscular flow a thousand times greater than the foreseen value.

To explain this discovery, Van Allen and his team of researchers from Iowa University took up a hypothesis advanced half a century before by a Norwegian, Stormer. He had envisaged the possibility that the earth’s magnetic field acted like a trap and that it imprisoned particles.

The American scientists supposed that at an altitude between
621 and 3,100 miles the earth’s magnetic field enclosed within its lines of force a great number of particles, forming an electrified band which circled the globe above the low altitudes: the earth was surrounded by a radiation belt, a kind of huge reservoir of electrified particles.

Other satellites, penetrating deeper into the cosmos, revealed a second radiation belt farther away, thicker, more extensive, and more fluctuating than the first.

The first belt lies between 621 and 3,100 miles up and is around 2,500 miles thick. The particles which had swamped the instruments of the first satellites are protons of very high energy (up to 700 million electron-volts). But they form only 1 per cent of this radiation zone which consists essentially of low-energy electrons.

The density of the inner belt varies relatively little, which makes scientists think that it is not dependent on the changeable and capricious sun. It seems to be maintained by the albedo-neutronic effect. That is, neutrons, produced by cosmic rays reaching the atmosphere, penetrate the magnetic trap owing to their electric neutrality. There they disintegrate.

One of the most curious peculiarities of the inner belt is its eccentric arrangement in relation to the earth. Its lower limit goes below 621 miles above the Atlantic, while it is more than 930 miles above the Pacific. The disposition of this radiation zone depends on the lines of force of the earth’s magnetic field. Therefore the latter must be eccentric.

This observation may confirm the theory of the Hungarian geophysicist Gyoergy Barta. He believes that the earth’s core, which generates magnetism, lies not at the centre of the earth but a few dozen miles away from this ideal centre. Under the influence of luni-solar attraction, it may be dislodged in the interior of the earth, causing the general westward drift of the magnetic field.

The earth’s eccentric magnetic field originates 310 miles from the centre. This is obviously quite astonishing, but there is no other hypothesis to account for this constantly confirmed observation. This is one more mystery to enter in the file on terrestrial magnetism.

The outer belt, on the other hand, is maintained directly by solar winds, which inject particles into it. It therefore shows the
characteristic instability of all solar phenomena. It moves between the altitudes of 12,420 and 50,000 miles, with a thickness of 6,200 miles and a corpuscular density which can increase tenfold in a very short time. The particles of which this region consists are essentially electrons, the highest energy of which reaches two million electron-volts.

In the radiation belts, the particles are caught in a real magnetic trap. One force, known as "Lorentz’s force", makes them roll in a spiral around the lines of force of the earth’s magnetic field. They plunge down to the polar regions in a corkscrew movement, where they rebound in the opposite direction. When they reach the opposite polar regions, the same phenomenon pushes these back again. The coming and going takes place in a matter of seconds. But at each rebound, the particles return following a slightly different longitude. The electrons shift to the east and the protons to the west. The particles execute a savage dance around the globe, endlessly thrown from one pole to the other.

THE LAND OF ENCHANTMENT

Among celestial phenomena, none is more spectacular than the polar auroras. These illuminations still remain a mystery to geophysicists. The mechanism itself is known—it is that used in neon tubes—involving luminescence caused by the excitation of atmospheric molecules of nitrogen and oxygen by the passage of a flow of low-energy electrons. By photographing the same aurora simultaneously from different angles, it was discovered that they originate between 62 and 620 miles above the earth.

The problem is obviously to know the source of the flow of electrons which causes the luminescence and why it appears at a given moment. Prolonged observation of the phenomenon showed that it is in relation to the earth’s magnetic field and solar activity. It is established that the most brilliant auroras occur during magnetic storms, which are themselves caused by solar eruptions. It has been observed that the time frequency of auroras follows the eleven year cycle of solar activity.

There is no doubt, then, that auroras are a sign of interference in the geomagnetic field and of solar activity. We are led to
believe that the electrons in auroras come from solar winds. It remains to find out what happens between the time that the electron travels in the solar wind, in interplanetary space, and the time that it reaches the ice in Greenland.

The discovery of the radiation belts gave scientists great hopes. It can be established that the auroral zones correspond with the borders of the radiation belts. It was natural to think that the electrons responsible for auroras came from these belts.

During the “Argus” experiment, the Americans exploded an atomic bomb at high altitude. As expected, the particles produced by the explosion formed an artificial radiation belt around the earth. But they also gave rise to auroras, the first to be artificially produced. The date of the project had been kept secret, and observers thought it was a natural aurora.

Professor Van Allen advanced the hypothesis that the radiation belts acted as reservoirs in which particles of solar origin were stocked and speeded up. At the time of eruptions, a new corpuscular injection took place. Then the belts overflowed, and the surplus electrons were thrown down above the subpolar regions, causing the auroras. Observations made since that time have compelled scientists to complicate oddly this over-simplified outline. Explorer 12 made it possible to calculate first of all that the number of electrons contained in the outer belt was a thousand times less than the flow of electrons which accompany auroras. Furthermore, these electrons are of much higher energy than that observed during these phenomena.

In magnetic storms, the outer belt is not saturated; on the contrary, it is completely emptied in the first 24 hours before being refilled. So it is possible that the belt, as it empties, supplies at least part of the flow of electrons in auroras.

Thus the presence of two belts, stocking and accelerating the particles, is not enough to explain the outer atmosphere. To try to find the explanation, scientists have begun a deeper study of the magnetosphere as a whole.

THE MAGNETOSPHERE IN THE SHAPE OF AN EGG

As its name indicates, the magnetosphere is a zone which is
defined essentially in reference to the action of the magnetic field. It begins at the level where atmospheric conditions permit the capture of the first particles by the lines of force of the magnetic field, that is, at about 370 miles, and ends when this field stops exerting an appreciable influence, around 62,000 miles. This marks the end of the earth’s domain. Beyond this limit, the planet’s influence is felt only through the action of its field of gravity.

The magnetosphere is shaped, not like a sphere, but rather like an egg, for it is constantly compressed within the hemisphere brightened by the sun. It measures 62,000 miles according to its longest radius—that of the dark hemisphere—and 37,300 facing the light. In a period of paroxysm in the sun’s activity, this radius can be reduced to 25,000 miles by the compression of the earth’s magnetic lines. The first characteristic of this zone is that it shows two huge voids above the poles. In these regions, the magnetic lines, being perpendicular to the surface of the earth, attract the particles directly toward the sun. Therefore there is no permanent corpuscular density there. This will perhaps make it necessary to construct cosmodromes in high altitudes to spare the first interplanetary travellers the dangerous crossing of the radio-active belts.

It seems that outside the Van Allen belts the magnetosphere contains practically equal quantities of protons and electrons according to the different categories of energy. In the upper part of the magnetosphere, the protons are weakly charged, for the magnetic intensity there is not great enough to capture the heavy high-energy particles. The latter can only be trapped by the more intense field over the lower levels.

The equal distribution of protons and electrons probably comes from the electric neutrality of the solar winds, which contain as many negative as positive particles. The magnetosphere is therefore constantly and equitably supplied with opposite particles.

Even outside magnetic storms the magnetosphere is not a tranquil world. The satellite Injun I established that an intense corpuscular flow streams perpetually out of the magnetosphere into the atmosphere. The electron belt appears, at the most, as a short transit zone for the particles.

However, it is physically impossible for the particles to reach the
ground during polar auroras merely crossing the magnetosphere and then the atmosphere. By the time they reach the frontiers of the earth, they do not have sufficient force to pierce its magnetic defenses, whether those of the magnetosphere or those of the atmosphere. They can only penetrate them if they are accelerated.

This fact was established experimentally. In April 1960, Pioneer 5 crossed a cloud of solar plasma which had just been expelled by the sun. Its geiger counter did not register a single particle. The conclusion had to be that the energy of the protons and electrons was no more than a few hundred electron-volts. Soon afterward, Explorer 7 observed the arrival of the corpuscular flow in the outer belt. The energy of the particles was a thousand times greater. Astrophyicists were led to believe that a mysterious acceleration zone for particles existed in the confines of the magnetosphere. Observations brought before the COSPAR congress in Florence in May 1964, by the Soviets as well as by Americans, fully confirmed this hypothesis. Explorer 18, in particular, revealed the existence of a zone of high turbulence at the magnetosphere, principally in the region facing the sun. The interaction between the earth’s magnetic field and solar winds would give rise to magneto-hydrodynamic waves (rather like ultrasonic waves) which would supply the particles with the energy necessary to strike the earth, like the stroke of a tennis racket hitting the ball across the court.

In this perspective, the Van Allen belts have only a secondary function. They lie slant-wise to the corpuscular flow, which travels through the magnetosphere, like traps, and they stop certain particles, which begin to turn in a spiral above the magnetic lines of force before pouring down into the “polar gaps” on the occasion of an aurora.

ATMOSPHERIC CRISSES

The mass of the atmosphere is subject to the double influence of the earth and of the sun. When either behaves abnormally, its precarious and fluctuating equilibrium is threatened. An atmospheric crisis occurs.

The surface of the earth heats up the lower layers, the tropo-
sphere. Excessive disequilibrium in this heating can cause crises in the lower atmosphere: hurricanes, storms, typhoons, etc. These phenomena are directly and painfully perceptible by us.

But solar activity is even more changeable and capricious than that of the earth. These fluctuations have repercussions essentially on the part of the planet which is directly in contact with the star: the upper atmosphere. These crises of solar origin were long unknown to man for they have the peculiarity of appearing only to men with a certain level of technical civilization. Indeed, they were discovered, little by little, through inexplicable disturbances paralysing radio-electric or magnetic phenomena.

One of the first observations concerned magnetism. The compass sometimes behaved very oddly; it would spin, then sensibly go back to pointing north. As early as 1741, Hiotter discovered that the oddities in the compass corresponded with the appearance of the most splendid aurora borealis. Later these magnetic disturbances came to be connected with the activity of the sun.

Then came the development of electricity and telecommunications, giving man a sure means of watching the upper atmosphere.

When the first repercussions of ionospheric crises were registered, technicians were thrown into a state of confusion. Among these repercussions were: a submarine that stopped sending signals; electricity no longer passing through high tension wires, plunging entire towns in darkness; railroad signals moving to "stop" of their own accord; radio contact suddenly vanishing; underwater cables stopping all service; private telephone calls being carried off and transmitted over the radio, etc. In short, the world of electromagnetism had quite unforeseeable whims which seriously affected its use.

Gradually a common origin came to be recognized for all these phenomena. Every case involves disturbances caused by the state of crisis in the upper atmosphere following a fit of passion in the sun. Unusual electromagnetic radiation originating near the spots can bring on disorders, especially in the earth's magnetic field. But true ionospheric crises follow solar eruptions. In this case, the star begins radiating violently throughout the scale of electromagnetic waves, even going as far as to emit soft cosmic rays.

This radiation reaches the earth in minutes and considerably
increases the ionization of the upper atmosphere. Then the ionospheric reflector will be functioning in very special conditions.

The electronic concentration in layer D become such that it strengthens long waves (which it usually reflects). Medium waves will be able to be reflected there, thus avoiding crossing this layer that weakens retransmission. Consequently a clear improvement is registered in telecommunications by using long and medium waves. On the other hand, short waves, which cross this layer unhindered and are reflected on layer F, strike against so many electrons that they are completely absorbed.

All telecommunications do not therefore become impossible. Some are achieved in abnormally favourable conditions. Sometimes ionization becomes so strong that the shortest waves are reflected. Thus, in 1957, five years before Telstar, television viewers in Britain suddenly saw pictures from Italian television appear on their screens. The television waves, which normally pass through the atmosphere, had been reflected.

Twenty-four to 48 hours after an eruption, the magnetic cloud of solar plasma reaches the vicinity of the magnetosphere. The lines of force of the earth's magnetic field recoil before the attack. In this way the whole ionosphere is compressed and ionospheric currents are considerably amplified. This atmospheric electricity in turn upsets the earth's magnetic field.

Logic would have these magnetic and ionospheric storms released first in the hemisphere facing the sun. In fact, the storm begins over the whole planet at the same instant.

We do not understand any better the disturbances to which terrestrial magnetism is subjected. It seems that the intensity of the field increases at first. Afterward, the magnetic field undergoes rather confused variations for several days before recovering its normal state.

During this time, the outer Van Allen belt empties and layer F2 disappears, although we do not exactly understand the mechanisms of these phenomena. Space research is scarcely ten years old, and geophysics (with truly interplanetary resources at its disposal) is hardly any older. We cannot demand definitive explanations from sciences so new. At present, we do not know how the earth
—the earth-system in its entirety—"digests" the cloud of solar plasma.

It is evident that the records of the upper atmosphere produce more questions than answers. But each question represents a great victory for science. From now on, astrophysicists know what the atmosphere is: the terrestrial organ responsible for maintaining contact between the earth and the sun. This new view indicates to them the directions in which to undertake research, and it poses real questions. From now on, terrestrial space is at issue.
We are coming closer and closer to regarding the life of the earth as a ceaseless struggle between the internal dynamics generating the rock and the solar energy which destroys it on the surface. But this planetary dialectic is upset by the presence of the living world. Lying on the surface of the globe, on the interference level of these two opposing forces, life appears more and more as an essential piece of machinery in the terrestrial system, as the “biosphere”, according to the name given to the living world by Suess.

Today, science is finding everywhere an unremitting phenomenon of adaptation between life and inanimate matter, and not an indifferent coexistence. A planet without life would only very remotely resemble our own. The living world has never stopped transforming and moulding the earth since its appearance; and this intervention in the general functioning of the earth becomes more significant every day as evolution pushes life toward its complete fruition.

Life intervenes between the earth and the sun in order to “treat” the radiation from the latter. Living organisms absorb part of the radiation and “break” the action of the agents of erosion (temperature variations, rivers, wind, etc.). Where this “layer of life” does not exist, in deserts for example, solar energy releases mechanical forces of erosion which quickly triumph over the mineral.

But the biosphere protects the rock only to destroy it more effectively. Thanks to solar energy, it draws from the rock the elements it needs to build up organic matter. It therefore destroys the mineral chemically, while the direct action of the sun works essentially through mechanical processes.

The intervention of the living world in the life of the rocks slows down the rate of erosion and makes it a process of chemical
decomposition, not of physical destruction. The results of erosion are very different according to whether or not the biosphere intervenes between solar radiation and the rock.

A PLANETARY CHEMICAL FACTORY

Not long ago it would have seemed daring to ask the question "what is life?" Now, there is no doubt that we shall have the answer in years to come. While we wait for the great secret to be discovered, however, the living thing is characterized by its manifestations. We describe it, for want of the ability to find its fundamental definition in its nature. But description becomes more and more difficult as biology progresses.

We can no longer settle the exact boundaries of the living world because there are none. In 1963, after a very long series of experiments verified by the most eminent Soviet specialists, Professor Tchoudinov demonstrated that algae fossilized in deposits of marine salt since the Primary Period could be brought back to life.

Thus the distinction between animate and inanimate no longer seems to have any meaning at the level of the elementary organisms. Today it appears to science that the relationships between the living and the non-living are at once more complex and deeper than was thought.

However, even if there is no break in the boundary between the two worlds, life constitutes a phenomenon completely characteristic in its manifestations.

The living is distinguished in the first place by its substance, organic matter. Its basic material is carbon, which plays to some degree the part of silicon in the mineral world. It is associated principally with oxygen, hydrogen, and nitrogen, in huge molecules totally different from the elementary combinations recognized by mineral chemistry.

This organic matter is combined into organisms, that is, into independent unities, each possessing the essential character of the vital functions. Fifty thousand billion tons of living matter are distributed on the surface of the earth in some four million species. The biosphere as a whole is engaged in elaborating living matter
from minerals. This operation, achieved first by plants, requires a considerable supply of energy. The chlorophyll pigments of plants find this energy in sunlight. Thus they achieve photosynthesis which results in the manufacture of highly complex molecules locking up considerable energy.

This organic matter is hungry for oxygen; it is combustible. Its oxidation obviously results in the liberation of the energy retained in the organic molecule. In this way organic matter supplies animals with 100 kilocalories for 10 grams of organic carbon.

**UNIVERSAL INTERDEPENDENCE**

Animal life needs organic matter and free oxygen to subsist. These two elements are supplied by the work of the plants; and this vegetable activity is itself only sustained thanks to sunlight. In a word, the sun is the provider of calories for the whole biosphere.

The development of the living world takes place in such a way that generally one species exists to undo what another has done, or to do over again what another has undone. Certain living organisms synthesize living matter, others decompose it, plants reduce carbon dioxide, animals oxydize carbon, some bacteria (called nitrifying bacteria) hold nitrogen, others (denitrifying) release it. It is of vital interest to each species, moreover, that its action be counterbalanced by another in the opposite direction.

The result of this complementary chemical action carried out by living species is to make different elements turn in endless cycles. Bacteria contained in the ground hold atmospheric nitrogen atoms in molecules of ammonia and nitrates. These compounds are assimilated by the plants, which cause the atom to penetrate the biosphere. According to circumstances, it can pass from the plant into a herbivore and from there into a carnivore. In any case it will end up as a corpse, attacked by those micro-organisms which will destroy the framework of the organic macromolecule. Then, the different bacteria relieving one another, the nitrogen atom passes from a molecule of ammonia into a molecule of nitrous acid, then to nitric acid, finally to be carried to the atmosphere by denitrifying bacteria.
This outline is obviously theoretical, and reality always has more imagination than theory. But the process as a whole is verified, although using different mechanisms, for most of the basic elements: oxygen, carbon, sodium, sulphur, etc. The huge chemical factory, which the biosphere constitutes, ceaselessly captures atoms of inanimate matter, and, after making them go through a more or less long and more or less varied itinerary, releases them only to recapture them eventually.

But the biosphere does not always restore what it draws in, as in the case of nitrogen atoms. It often forms new materials which are incorporated in the earth's crust. In this case, biological action leads to decisive geological results and is not satisfied with maintaining a current of matter on the surface of the globe. In addition, this interdependence which unites the living world and this complementarity which marks the action of the different species enable the biosphere to perform a very important regulative function in the planetary system. Numerous imbalances can be reabsorbed in this perpetually evolving world. Thus life helps to keep constant the amount of carbon dioxide in the atmosphere, the composition of sea water, etc.

**BIOGEOLOGY, SCIENCE OF THE FUTURE**

We still know very little about the geological role of the biosphere. Scientists are not even unanimous about its role in the manufacture of petroleum. So it is much too early to attempt a biogeological synthesis. However, it is interesting to note that the latest research in this field has made possible the discovery of fresh aspects of biological intervention in the mineral world.

How does the biosphere, in practice, intervene between the mineral world and the sun? When rock appears in the free air, germs of vegetal life, spores, settle in the anfractuosities. Lichens will be able to develop on the rock if there is sufficient moisture. Later, higher forms of vegetation will appear. In the course of their development, the plants decompose the rock by drawing from it the elements they need, corrode it by sending out acid by-products, crack it with their roots, etc. In this way a layer of
earth is formed, soil composed partly of organic waste and partly of decomposed rock.

If the covering of plants thrives until it forms a forest, mechanical erosion will no longer be able to operate normally. A forest stabilizes climatic conditions at ground level, breaks the wind, levels temperatures, etc. In addition, the loose ground shelters the rocky substratum from the mechanical forces of erosion.

The leading part played by the forest covering in the erosion cycles was especially elucidated by the French geologist H. Erhart. Erhart holds that forestation results in selective chemical erosion which carries to the sea only some elements of the rocks, essentially the alkaline metals. What is left of the decomposed rocks accumulates on the spot. This is why forest rivers are limpid, while those in unforest regions carry aggregations of mud.

When a forest disappears, erosion takes to the sea the sedimentary mass left by biological erosion. To Erhart, the whole history of sedimentation in the course of the geological ages is explained by the alternation between chemical erosion in periods of forestation, and detritic (i.e. mechanical) erosion when forests disappear. He calls this the bio-rhexistasic theory.

Thus some sedimentary rocks, like limestone, correspond to the period when the forest filter sends only certain elements to the sea. On the other hand, clayey bauxite sediments correspond to the general lixiviation of soil after deforestation. This would explain the differentiation between sedimentary series.

Why do the different continents pass through periods of forestation and deforestation? Erhart does not venture to formulate any hypothesis on a problem which is tied to the general mystery of climatic variations in ancient times. He contents himself with establishing the periodic destruction of forests and their renewal.

The soil, the interference level between animate and inanimate, possesses unusual dynamism. Scientists who study soil have calculated that 2,471 acres of garden contain one ton of microorganisms and 130,000 earthworms, which are so active that they take all of the upper soil into their organism in a few years.

Supporting such a high density of life allows no rest at all to the
minerals. By its chemical activity the biosphere keeps on decomposing new layers of rocks from which it draws its substance. The rock is then changed into soil before being carried away by the usual transporting agents of erosion.

Biological activity plays another essential part in sedimentation—the formation of new rocks from the products of erosion. The huge mass of sediments which reaches the sea each year (3,116,000 cubic miles) maintains a microscopic marine flora and fauna: plankton. According to species, these minuscule creatures attract silica or limestone into their shells.

When dead, these organisms fall in a constant shower to the sea floor. It is thought that the organic matter of their corpses can, in certain circumstances and through little-known processes, be the prey of anaerobic bacteria which will eventually change it into hydrocarbons. Each organism will produce only the tiniest drop, which will begin to make its way into the porous ground formed by the sediments. All these particles finally congregate and form petroleum beds.

Living organisms can also form mineral beds (coal, iron, sulphur, phosphates, etc.) by concentrating certain elements or isolating them.

We must repeat that we are far from having examined and synthesized the geological activity of the living world as a whole. But what we do know of it shows that life helps in an important way to make the terrestrial system "go".

**IS LIFE AN ALCHEMIST?**

The essentially chemical activity of the biosphere boils down to construction work, with atoms as the fundamental bricks. In chemistry, according to the rules of the game, atoms can be assembled in different ways, but the atom itself cannot be changed. This is the basic law of chemistry and one of the fundamental principles on which science has been built up to the present. A modification of the nature of the atom—the transformation of an atom of one element into an atom of another element—constitutes, not a chemical reaction, but a nuclear reaction. Only two reactions of this kind are known to science: the disintegration of a radio-

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active atom, and the fusion of two light atoms. These reactions put considerable amounts of energy in action.

The search for other possibilities of transmutation has been made by alchemists, not chemists. However, some “inconvenient facts” have led very genuine scientists to reconsider the problem.

In the last century, Von Herzeele made a very curious observation. He germinated a seed in distilled water, knowing the exact chemical composition of the seed, then re-examined it after the first appearance of growth. He found that some elements were more abundant, while others had diminished—simply by the action of the mysterious phenomenon of life, there being no external supply.

In recent years, Professor Baranger, director of the Polytechnic chemical laboratory, studied this phenomenon systematically. He established the average composition of vetch seeds in 2,000 experiments. Then he repeated the experiments on the same number of sprouting seeds. The two did not match. The number of experiments and the prestige of the scientist allow no doubt as to the results. All the evidence points to the fact that germination is accompanied by transmutations.

Another scientist, Louis Kervran, made a large number of bizarre discoveries. In some factories, welders are poisoned by carbon monoxide while the atmosphere of the workshop does not contain any. Hens lay eggs with calcareous shells while their feed supplies them only with potassium. Rats maintain their percentage of organic magnesium although they do not take in any. Workers in the Sahara oil fields lose more potassium than they absorb, but their losses in sodium are excessively small. Similarly, the surplus of magnesium in excretion corresponds to the deficiencies in calcium and phosphorus.

These observations led Kervran to the heretical conclusion that life can cause transformations. He believes that biological activity is capable of smashing the nucleus of the atom and displacing “bundles” of protons and neutrons in order to pass from one element to another.

To Kervran, these transmutation constitute a completely universal phenomenon: the biosphere acts through transmutations just as much as by chemical reactions. He points out that when one
establishes the magnesium content of wheat harvested annually from an acre of land and compares it with the amount contained in the soil, one comes to the conclusion that the crops should have stopped containing any long ago, in the absence of external supplies. For centuries rich lands have provided wheat with 12.8 milligrams of magnesium per 2.2 pounds. As to the source of this magnesium, he says: “Life draws it from calcium, itself obtained by transformation from silicon.”

This operation may be carried out by bacteria which attack silicious stones and cause gypsum (calcium sulphate) to appear on the surface. Professor Fusey is presently continuing experiments on this alchemic activity of bacteria. A transmutation of this kind may be found in the origin of saltpetre (nitrates of limestone, potash, and magnesia) which forms on calcareous walls.

A NEW ATOM

We have just seen that the formation of petroleum is generally explained as the decomposition of marine micro-organisms. Mr. Kervran disagrees: “It is the activity of bacteria which decomposes the calcium atoms from limestone into oxygen and magnesium and then breaks up the magnesium atom to make carbon. The hydrocarbons would come into being by the chemical combination of water and carbon thus produced.”

It is evident that, if Mr. Kervran’s hypotheses are verified, geologists would have to be wholly revised. The role of the biosphere in the general functioning of the earth-organism would become fundamental. For example, the biologist believes that there was much less calcium on the surface of the globe when life first appeared, and that the huge masses of limestone of biological origin are the product of transmutations which made this element appear where it did not previously exist. Our earth became encrusted like the inside of a kettle.

Today, scientists protest at Kervran’s ideas. They point out that the force of nuclear cohesion is the most powerful there is in the world, and that it would take a fantastic expense of energy to break up an atom. To overcome this theoretical impossibility, Mr. Kervran had to work out a new schema for the nucleus of the
atom. It is a hypothesis which should be capable of easy verification.

Mr. Kervran has specially drafted the following note in order to explain his research:

"It was acknowledged that the nucleus of the atom was a spherical accumulation of a mixture of protons and neutrons, the mass and radius of which were calculated in terms of the starting hypothesis. The average cohesive energy of the nucleons (protons and neutrons) was also calculated on these bases.

"Such a structure was incompatible with the results which I observed in more than six thousand experiments. I could not attempt an experiment on the plan of the structure of the atom except by supposing 'prefabricated elements', 'fritted' together. Otherwise stated, I thought that the notion of average energy was meaningless... in the same way as the average number of animals in a specific herd would be meaningless in counting elephants... and their fleas. I conceived the nucleus of the atom as made up of combinations of nucleons very strongly linked to one another to constitute specific entities, since my experiments led to the recognition that the displacements observed were those of nuclei of hydrogen, carbon, oxygen, and sometimes lithium (if there were others, I have been unable, so far, to find them). I was able to determine the displacement energy of a nucleus of oxygen in such a system.

"After the publication of my work, the Americans demonstrated interferences in a diffraction diagram of an atomic nucleus, and concluded that this showed the rotation of particles in the nucleus, which was therefore not a mass of 'joined' nucleons turning in one piece. It was thought that this observation could justify the already proposed hypothesis of concentric layers of nucleons like the concentric layers of electrons.

"But this 'onion skin' construction did not explain why hydrogen, carbon, and oxygen, especially, and more rarely lithium, were displaced. Later, the Americans conceded the hypothesis of 'clusters' of nucleons, the model thus defined being given the name 'cluster model'."

If these hypotheses were to be verified in the future, it would be one of the most important discoveries in half a century. A new
science would arise, as momentous as relativity or quanta physics.\textsuperscript{1}

\textbf{STILL THE SAME CYCLE}

If we hold to what we have said up to the present, life depends on the inanimate earth-sun-cosmos world only for the supply of raw materials necessary for it. The sun provides energy, the earth provides matter; life takes both and accomplishes its own work in total independence. The biological processes would be decided only at the level of the initial supply, but the “utilization” would remain as independent as that of electric power supplied to customers.

Can we be really certain of this? Would life, supplied with matter and energy in terrestrial conditions, be the same on another planetary system? We said that biological activity was essentially chemical: it is limited practically to the chemistry of colloids. All chemists, and especially those who work with colloidal reactions, know that the rigorously controlled initial supply is not enough to assure the success of a reaction. Even by reproducing with absolute scientific exactness the conditions of a previously successful experiment, one cannot be sure that a reaction will turn out normally.

Ten years ago, Professor Piccardi, director of the Institute of Physics and Chemistry in the University of Florence, decided to attack the problem. He chose a very simple colloidal reaction, a precipitate of bismuth oxychloride, and repeated it many thousands of times at all periods and latitudes. In 1962 he had completed 250,000 experiments. Apparently without reason, the precipitate worked or did not work, while the initial supply was rigorously the same. Examining the diagrams of successes and failures in terms of the different factors of time and place, Piccardi noticed that the cycles of solar activity and the influence of the galactic fields of force were found.

\textsuperscript{1}Kervran’s theories are set forth in the following works: “Biological Transmutations” (aberrant metabolisms of nitrogen, potassium and magnesium), 1962; “Natural Non Radio-Active Transmutations” (a new property of matter), 1963; and “Transmutations at Low Energy”, 1964, all published by Maloine, Paris.
Many other experiments have brought out the influence of astronomical phenomena on the behaviour of colloids.

The influence of the solar cycles also seems to make itself felt on biological growth. This has been supported by the study of growth rings in trees, which indicate an eleven year cycle. It has been claimed that harvests also follow this cycle, but here the observations are far less certain.

It is indisputable, on the other hand, that solar influence is felt by living creatures through terrestrial magnetism. The sensibility of living organs to magnetic fields is beyond doubt. Professor Rocard has showed that this magnetic sensibility explains the effect of the divining rod. In the United States, C. Wieske related the case of a woman who was subject to sound hallucinations as a result of electro-magnetic phenomena. Another American researcher, F. Brown, found that snails take their bearings from the earth’s magnetic field. Furthermore, a Soviet scientist, A. Bkrylov, proved that the magnetic field can influence the growth of plants; while H. Barnothy, of Illinois, stopped the growth of a cancerous tumour with a field of 4,000 gauss.

But it is acknowledged that there is no life in any magnetic field.

It seems that living creatures are magnetic receivers only for fields of comparable intensity to that of terrestrial magnetism. The German zoologist Schneider established recently that pigeons react to the variations in the earth’s weak magnetic field, while fruitless attempts had been made for decades to make them respond to fields of high intensity. It is therefore confirmed that life on earth is subject to the influence of its magnetic field. But we saw that this magnetic field is unstable, and that sometimes magnetic storms break out due to the sun’s influence. What happens then?

In this case, certain individuals particularly sensitive to magnetic influences become ill. This fact was confirmed in 1963 by the American researchers Friedman and Bachman who established an undoubted connection between the number of cases of mental illness and magnetic anomalies.

Solar activity seems to be particularly harmful to cardiac cases. Before the war, Dr. M. Faure, of Nice, had already shown that inflammation of the tissues increased in periods of great solar
activity. This relationship was made the object of systematic study by Professors Poumailloux and Viart, of Saint-Antoine Hospital in Paris.

The Soviets seem especially aware of the interdependence of solar, magnetic, and biological phenomena. At a conference on the subject, held in Moscow in the beginning of 1964, the conference were unanimous in confirming the relationship between geomagnetism and the physiology of living beings.

Subject to the magnetic field and, through it, to solar and galactic activity, terrestrial life is also bound to its environment by the earth’s field of gravity.

Again, recent research is involved, involving experiments the results of which are unquestionable. The American scientists Dodge and Wunder revealed the connections between the field of gravity and the growth of living things. Tortoises subjected to strong accelerations developed only very slowly, while an acceleration of 5 g. doubled their rate of growth. From now on, experimentation in this field will take place within the framework of astronautics. It appears that the physiology of terrestrial organisms cannot do without weight over a long period, and it is foreseen that artificial gravity will be created on future interplanetary ships.

All astronomical rhythms, the day, lunation, the year, eventually subdue living things. Their effect is found in the functioning of many organs, down to cellular activity. In order to discover the signal which “tells the time” to living organisms, guinea pigs were subjected to artificially uniform conditions of radiation, heat, pressure, etc.; it was a waste of effort—life was still on time.

Scientists have had to recognize the truth: living beings do not need anyone to keep time for them. They possess an inner rhythm which corresponds to the astronomical cycles and which follows them unfailingly. Terrestrial life is therefore subject to “earth rhythm”, just as life on Venus would adopt the “Venus rhythm”.

It would seem, moreover, that the phenomenon is even more mysterious, if one credits an experiment carried out by Dr. Frank Brown, of Northwestern University. He took some oysters, which open twice a day to the rhythm of the tide, and placed them in a basin where artificial light maintained continuous daylight. For
fifteen days the oysters yawned as they had always done; then they remained obstinately closed. Nevertheless, Dr. Brown continued the experiment, and he found that the oysters began to open again, but that they had adopted a different rhythm.

The oysters had been accustomed to open at high tide, that is, four hours after the passage of the moon at the meridian. Dr. Brown had moved them 900 miles. Consequently their rhythm no longer followed the passage of the moon, which varies from one place to another. They had therefore made the correction and had set themselves to lunar time in Illinois, and their openings were again following, by four hours, the passage of the moon above their shells.

Life is not only tied to the inanimate world by its need for matter and energy. It also depends on the sun’s caprice, on the fluctuations of the galactic environment, on the magnetic and gravitational fields, as well as on rhythms peculiar to the terrestrial environment.

This influence is only the counterpart of that exerted on the earth by the biosphere. The latter flows from the profound integration of life in the earth-organism. It is because terrestrial life is substantially a part of the earth that it influences it so strongly and is so strongly influenced by it.
21/Man’s Assault upon the Earth

As long as man lived by hunting and picking berries, his actions had scarcely any consequences on a planetary scale. Having discovered fire, he lit forest fires in order to flush out game. This still had no effect. The earth began to bear the stamp of the human race when man required agriculture and animal rearing to assure his subsistence. Land-clearing, that is, cutting down trees, became the first imperative. The forest began to retreat to make way for fields and pasture. As it lost its forest protection, the ground became more unstable. From this point onward the biosphere has been at the mercy of badly planned exploitation.

MAN-MADE DESERTS

Man has been making deserts in all kinds of ways since he first appeared on the planet. In some cases the earth was sterilized by his very efforts to fertilize it. The Sumerians made their fields arid by irrigating them with salt water. In other cases sterilization was caused by shepherds, or by wars. Indeed, man unbalances the biosphere by protecting herbivores and destroying carnivores. The pressure of fauna upon flora then becomes much too strong. Herds of goats and sheep have added thousands of acres of desert.

Waste land has increased by 20 per cent in the past hundred years. Although it is nearly impossible to establish statistics in the matter, it is probable that the balance between land reclaimed by irrigation and land taken over by desert is not favourable. Waste land continues to increase today.

Even where the biosphere has continued to exist, it has been greatly modified by the phenomenon of man. Man is the greatest
exterminator ever to appear on earth. The “sudden” disappearance of species revealed by palaeontology was actually spread over thousands or even millions of years. Man, however, can make species disappear in a few centuries or in a few decades.

By hunting and by producing waste land, man exerts implacable pressure on the fauna of the earth. And recent advances in chemistry have improved his destructive power ten times. More and more powerful insecticides—it would be more accurate to call them biocides—have been brought into action: D.D.T., dieldrine, endrine, aldrine, etc. Insalubrious regions became habitable, epidemics were stemmed, harvests were saved, diseases were conquered, human lives were spared. Was man about to subdue nature?

ANIMALS ARE DISAPPEARING

Today the enthusiasm over early success is giving way to concern. The works of Professor R. Heim, N. Strotsky, and R. Carson, make one wonder whether our successes are not Pyrrhic victories. The organic unity of the biosphere makes it impossible to foresee the consequences of human interference. Out of 800,000 known species of insects, it is estimated that only 6,000 are harmful. But the 350 million pounds of biocides scattered by Americans in 1963 do not make any distinctions. In some areas D.D.T. killed 80 per cent of the birds without destroying all the insects since they build up resistance to insecticides. In the United States a hundred harmful species were found to have become immune to the most deadly pesticides.

The destructive frenzy of mankind extends to the oceans with equal efficacy. New methods of fishing are successfully exterminating marine fauna. Rivers, having become sewers, are turning oceans into cesspools. The water of as important a river as the Mississippi is so loaded with endrine that it is killing the fish.

Tankers empty three and one-half billion tons of oil into the sea each year. Thus a hydrocarbon film forms which hinders the oxygenation of the water and exchanges between the atmosphere and the hydrosphere. On the English coasts, 250,000 sea birds die
of cold every winter because their feathers are coated with hydro-
carbon and can no longer protect them.

A NEW DELUGE?

Our atmosphere is getting dirtier every day. It is “enriched” by six billion tons of carbon dioxide every year. The dust caused by man’s activity is such that a quart of air from an industrial area contains almost a million particles of dust (the corresponding figure for a forest would be 20,000). New bodies have appeared in the atmosphere: toxic products, like sulphuric anhydride.

The dirty atmosphere of cities intercepts up to one-half of the sun’s radiation, increases precipitation, and causes a perceptible rise in temperature. It eventually creates a distinct urban climate, which is purely artificial and which tends to assume greater and greater importance.

Many signs indicate that the climate of the planet is becoming warmer. It is unquestionable in the northern hemisphere. The Russians have found that huge islands of ice figuring on old maps are no longer there. The average temperature of Greenland has risen 5° centigrade in twenty years. Muir Glacier in Alaska has receded 13.7 miles since the beginning of the century. Cod fishermen are moving further north to find fish. Observations are less precise for the southern hemisphere, but it does seem that the phenomenon is planetary.

If the Antarctic ice were to melt, the level of the seas would rise 260 feet, submerging Paris, New York, Tokyo, Rio, London, etc., and it would take only a few degrees for glaciers to start melting inexorably. Unfortunately, this threat is no idle fancy. We have seen that the carbon dioxide in the atmosphere causes a squeezing effect. The result of an increase in the amount of this gas is, therefore, to raise the average temperature of the planet. From the mere fact of human activity, this rise is of the order of one degree centigrade per century.

This artificial heating, added to a natural development in the same direction, could lead to disaster in a few centuries. A rise of a few yards in the level of the oceans would already be a world wide catastrophe.
The picture of the earth abandoned to man is already gloomy enough, and we have not even mentioned radioactive pollution (less dangerous than chemical pollution, contrary to general belief) or the threat of a thermonuclear cataclysm. But if man is an apprentice sorcerer today one may reasonably believe that tomorrow he will be the sorcerer who will transform the earth.

MAN WILL SAVE THE EARTH FROM MAN

Up to now, man’s actions on the earth have been essentially confused, unconscious, and short-sighted. The results have been disappointing in spite of advances made, but through scientific and technical progress, may we not go on to remodel the planet in a much more grandiose way, to perform a real “surgical” operation on the earth, so as to distribute rationally the continents, oceans, and rivers? Many years ago, bold spirits conceived such projects. The work required would have been no different in nature than much already accomplished. It was a matter of levelling mountains, closing channels, changing the direction of rivers, cutting transcontinental canals, etc., all these being conceptions which simply suppose new colossal dimensions. But it seemed that with achievements like the Suez and Panama Canals, the harnessing of the Tennessee, the Volga, and the St. Lawrence, the drainage of the Zuiderzee, the Simplon Tunnel, the maximum of the possibilities offered by classic procedures had been reached. By comparison with these methods, conceptions on a greater scale would appear disproportionate. In the future, nuclear explosion should make it possible to complete the biggest tasks with exceptional rapidity and economy. To level a small mountain by this method does not cost more and takes less time than to dispose of a hill employing classic methods.

In 1957 the Americans initiated Project Plowshare to develop nuclear power as a tool. Since that time, underground explosions have been going on in Nevada to perfect the technique. Urged by political necessity, the United States, wishing to make use of nuclear explosive power as soon as possible in order to cut a second Panama canal, quickened the pace of these experiments in 1964. However, the technique is still far from ready. Professor Seaborg,
the most eminent authority on the matter in the United States, estimates that it will be another five years at least before nuclear earth-moving enters its industrial phase.

Is this still science, or is it daydream? When the winner of a Nobel Prize for chemistry foresees the creation of stations on the moon for the purpose of reflecting sunlight, is it science fiction or pure science? Let us simply say that this is the prediction of a visionary, that is, that his expectations have an indicative value. Perhaps the projects imagined by Professor Semenov, Sorgel, and many others will not be effectively realized. This does not matter. Those which take their place will not yield anything to them in the realm of the fantastic. Whatever the means employed, our earth is called upon to bear more and more deeply the stamp of men.
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