Translation of Pallas' theory of the earth (1778)

CHAPTER III

TRANSLATION OF PALLAS' THEORY OF THE EARTH (1778)

PALLAS' THEORY

On the Nature of Mountains and on Changes which have occurred on the Globe, particularly in the Russian Empire. Read at the Public Meeting of the Russian Imperial Academy of Sciences on June 23, 1777, Honored by the Presence of the Distinguished Count von Gothland.* Frankfurt and Leipzig, 1778.

OBSERVATIONS ON MOUNTAINS AND CHANGES WHICH HAVE OCCURRED ON THE GLOBE

Since the renewed interest in sciences, one hypothesis after the other has tried to account for the apparent structure of our planet, the origin of its mountains, the presence of layers which include marine fossils, and other traces of great changes at the surface of the Earth. These changes are mentioned in the ancient history of most Asiatic peoples, but naturalists have tried to find or propose natural causes for these changes. Most hypotheses (p. 4), from the collapse of an ancient Earth crust, to the most modern interpretation of Count Buffon[1] and other famous authors of our century, do not lack in correct observations and appropriate conclusions. However these conclusions are all mistaken because the authors relied merely on a few or even one particular observation and cause from which they wanted to deduce all effects of Nature — so richly endowed with resources — and hence they became lost in imaginary explanations and arbitrary guesses. To explain the structure of the entire Earth, they relied not only on national prejudices but also on their individual sphere of knowledge on mountains in their native country. Several of these creators of hypotheses have never even seen great mountain chains, or at least only those which cross Europe; their theories thus refer to the particular structure in a nearby mountain, and often only to a small part of it which is easily accessible. The behavior of these naturalists is thus similar to that of the ancients (p. 5), and of some modern Italian authors too, who explained the ebb and flow of a worldwide ocean on the basis of small movements in the conveniently close Mediterranean Sea. Woodward,[2] for instance, ignored mountains that consisted of very old rocks

* The King of Sweden.

and built his system about the formation of layers and mountains during the Deluge on his erroneous belief that all mountains of the Earth consist of almost horizontal strata. Even Count Buffon seems to have judged mountains in general based on those found in France which consist in fact of nearly horizontal layers, sometimes merely thrown up and disarranged by fire-spewing mountains. Otherwise he would not have concluded that granitic pebbles, and even the old granitic mountains themselves, originated from sediments that had been transported and deposited by ocean currents (1); nor would he have stated that traces of the sea are still visible on the highest mountain (p. 6) tops; (2) that these mountains, as well as the plains, consist mostly of horizontal strata (3); and that fire-spewing mountains exist only underneath high Alps (4).[3] All these statements are totally or partly contrary to the general laws of Nature. Many Italian naturalists have witnessed violent eruptions of still active volcanoes in their own country and noticed frequent traces of extinct ones. They believed therefore that underground fires are responsible for everything. A learned mineralogist from Austria (Mr. Delius)[4] having observed calcareous rocks (perhaps only calcareous in appearance) in the Carpathian Mountains, believed that all the high mountain chains everywhere on Earth, even their substratum or the interior of our planet itself, must consist of these rocks. Many more examples of this kind could be mentioned, but (p. 7) I have not planned to discuss here all of the many ancient and modern hypotheses on the present state of the Earth. Most of them refer either to the collapse of an initially smooth and solid crust which surrounded the former Earth [Burnet]; to the flooding of land caused by a displacement of the sea from its shores, imagined in various ways; to the sudden dissolution of the Earth's crust during the Mosaic Deluge [Woodward]; to the effects and even the push of a comet which happened to fall into the orbit of our planet [Buffon]; or to the slow and general diminution of the sea. Finally, fire-spewing mountains have also been invoked. Many naturalists have described them as the effects of an alleged central fire; others have made this central fire responsible for the creation of metals by sublimation and for the origin of springs by distillation. Thus our planet was supposed to be now a laboratory of chemistry, now a hydraulic machine, more adapted to the methodical ideas of sophistical minds (p. 8) who take pleasure in such arguments than to the great and manifold processes of Nature which, when closely observed, often destroy the most beautiful systems — even mathematical demonstrations — concocted in a study.

Some general information about the nature of the Earth's surface and the great primitive chains were made available only recently. Swedish and German mineralogists[5] were the first to formulate some clear and concise ideas on the order followed by Nature in the formation of these elevations and the arrangement of the composition of layers in the hills and plains of our continents. Under the auspices of our great and sovereign Empress, I have crossed almost the whole width of Asia and a large part of the two most important mountain chains that support the inhabited

world. I am pleased that the results of my observations, which were done without knowledge of recent discoveries, (p. 9) and hence followed no preconcieved ideas, agree in all respects with those of the Swedish and German naturalists. Furthermore, my work helps to confirm the intelligent and true concepts which they have proposed on the interior structure of the globe.

I am presenting here a synopsis of relevant matter scattered throughout the journals of my trip[6] in order to extend the above ideas to the vast Russian Empire and also to provide a clearer picture — based on my own experience — on the former state of our Earth and its catastrophes.

According to our present knowledge of the Swedish, the Swiss, and the Tyrolian Alps, the Apennines, the mountains surrounding Austria, the Caucasus, the mountains of Siberia, and even of the Andes, one can accept the following principle: that the highest mountains on Earth (p. 10) that form continuous chains are all composed of rocks called granite. Its components are always quartz, more or less mixed with feldspar, mica, and small amounts of basalts [mafic minerals], distributed randomly, in irregular fragments and various proportions, but evenly fused together.[7] Based on observations at the surface and inside the Earth's crust (in mines and wells, although of insignificant depth for a comparison with the mass of our planet), it can be concluded that this old rock and the sand and gravel formed by its destruction, are the basic materials of all the continents. Granite occurs underneath the deepest layers of mountains and in lowlands where strata were removed during violent floods; granite forms the great bodies or vast watersheds and, so to speak, the heart of the highest mountains of the known world. Therefore, it can be considered quite reasonably to be the main component of the Earth's interior. I must admit (p. 11) that such a constitution does not favor the theory of a central fire whereas naturalists, who place a huge mass of magnet in the center of the Earth, might be better off because magnet, which is always mixed with mica and often with quartz, seems closer to granite than inflammable minerals or limestone and pure sand, with which, according to others, the Earth is supposedly filled. Moreover, granite may seem to have been originally in a state of fusion and hence a result of fire.[8] Buffon and others who accepted the idea that a comet separated all the planets from the sun — or that comets burned and molten by the fire of the sun form all the bodies of our solar system — explained easily the apparent glassy state of the oldest rocks because it has not yet been sufficiently demonstrated that the sun burns in this manner and that its fire is strong enough to keep its mass in a state of fusion (p. 12). I believe that it is beyond human understanding to ever find the real causes that placed such an enormous mass of glassy matter in the orbit of our planet. The ingenious author of *Recherches sur les Américains*[9] seems to be right in saying "that it is no more futile to write about the creation of stars than to give an explanation on the creation of mountains which were elevated by the powerful hands of Nature to whom we owe the small planet where philosophers are reasoning." Nevertheless, general and

constant observations show that this old rock material that we call granite, which never occurs in layers but in entire blocks or at least in *Wacken* [superposed masses],[10] contains not the smallest traces of petrifications or imprints of organic bodies and thus appears older than the entire living Nature. If we accept Indian and Egyptian time chronologies of the world, the Earth must at least have been reduced to the state in which we find it today by (p. 13) a general fusion which destroyed the smallest traces of any organic body which existed before such a catastrophe. We also notice that the highest elevations on Earth, whether in high plateaus, mountain ridges, or jagged rocky peaks, are never covered at high elevations by argillaceous or calcareous layers that originated in the sea, but that they seem to have always been dry and above sea level (5). Another observation (p. 14) refutes the opinion of naturalists who consider all mountains and elevations on Earth as the effect of a central fire and its eruptions during the first times in the Earth's history when the crust surrounding this formidable fire was not solid enough to resist equally the internal forces of that fire everywhere. This would certainly not have happened without lifting simultaneously various different [non-granitic] layers of which (p. 15) some traces ought to be found on the high and steep peaks of granitic mountains. A single example of this kind would indeed prove that subterraneous volcanic eruptions could possibly originate underneath granite or from its center. Until today these searches have remained fruitless although the location of fire in several recently investigated extinct volcanoes seems to have existed immediately above granite.

I shall describe here the highest elevations of these old rocks in the Russian Empire and in northern Asia based either on personal observations or reliable sources. Recent travels have shown that the Caucasus, situated between the Caspian and the Black Sea, is one of the highest granitic mountains on Earth. As in all other mountain chains, this granite is usually surrounded by bands of schists and limestones as well as by later deposits, arrangements that shall be explained later on in more detail in regard to the Siberian mountains. The mountains (p. 16) on the southern shores of the Caspian Sea are not so well known, but the little I have heard tells me that they probably consist only of schists and limestones and that they seem to have been lifted to considerable heights by subterraneous fires[11] which seem to have also formed Mount Ararat (which is perhaps connected with this chain), fires that are not yet completely extinct in the Persian mountains. I have mentioned these first Asian mountains very briefly in order not to intrude on a detailed account to be given by Professor Güldenstädt.[12] I shall be more specific about mountains which I have studied myself.

The Ural Mountains have been famous for a long time. Today they are particularly well known because of the many metallurgic industries and the numerous naturalists who have crossed them in all directions. The natives call the Ural respectfully the "belt of the Earth." (p. 17) Strahlenberg described it properly as the natural boundary between Europe and Asia[13]. Granite and quartz form here only a narrow

ridge which meanders from south to north. The largest width of this ridge is above the springs of the rivers Jaick (Ural) and Belaya where it is strenghtened by some high mountains which have branched out from the main mountain chain. There granitic rocks crop out in the middle of the band of schists, in particular on the west side. From here on, the ridge of granite continues scantily, diminishing above all in height; it is often covered and at the same time interrupted by its adjacent band of schists until it reaches the spring of the river Tura. Further to the north, the ridge of granite widens again, displaying high mountains between the springs of Kama and Pechora on one side, and the waters which run eastward into the Tawda on the other. (6) Finally, (p. 18) the granite ridge, still jagged and rocky, diminishes toward the coasts of the Kara Sea where it forms either the fore-range on the west side of the mouth of the river Ob, or turns north-eastward, along the coasts of the Kara Sea, branching out through (p. 19) the Strait of Waygat to form Novaya Zemlya. Through steep coasts, rocks, and islands, this granitic ridge finally joins the great chain of Lapland which, after having crossed all of Scandinavia in the form of a horseshoe, fills the lowlands (p. 20) of Finland with granite and other rocks. This chain seems to continue from the other side of the North Cape in Norway through the Spitsbergen, filling perhaps the Arctic Ocean around the North Pole with islands and (p. 21) sunken rocks, and reunite after the polar region with the northern and eastern points of Asia and North America. This continuity seems to give great credit to the most common natural laws in regard to the connection of mountain chains on Earth. It seems to bring to naught any future European commercial ventures of reaching China and Japan by way of the North Pole.

From a region of apparent greatest elevation, the Ural Mountains diminish constantly toward the south beyond the river Jaik [Ural] where they finally split up into small hills of schists and *Flötzgebürge*[14] that spread out between east and west into Southern Russia, the regions around Lake Aral, and the western branches of the Altai Mountains.

I shall now give a general description of the latter which is part of one of the greatest mountain systems on Earth. The entire Altai Mountains, which form the southern boundary of Siberia from the river Irtysh to the [Pacific] Ocean, is only a (p. 22) branch of this great system of which I shall give a sketch that differs widely from what has been said until now. First, not all mountains on Earth form continuous chains, following various directions, nor are they, as Bourguet[15] stated, directed either along the meridian or the equator where they cross each other at right angle; nor do they form, so to speak, the ribs fixed to a common spine. These ideas, among which the latter are most familiar to Swedish mineralogists, were also based merely on some characteristics of specific countries where they originated, but do not agree with the general plan of Nature. In some mountain-systems, branches or chains unite in one or several adjacent centers or in a common watershed which govern all other chains by their elevation. This seems to be the case for that great mountain which

sends branches or rays in different directions through the entire interior of (p. 23) the Asian continent, representing the first inhabited land in this hemisphere. The shape of the African continent seems to point to a different distribution and arrangement of mountains; however, the interior of that part of the world is not known well enough to form any good judgment.

To reach the highest elevation in Asia, the safest and most commonly used method is to follow upstream the greatest rivers to find their initial springs from where they flow into seas in opposite directions. The Indus and the Ganges, which flow into the Indian Ocean [Arabian Sea and Bay of Bengal respectively], as well as the Yellow and the Yangtse rivers, which cross China and flow into the Eastern Ocean [Yellow and East China Sea respectively], have their main sources in the mighty mountains to the north of India that surround Tibet and the [former] princely state of Kashmir, so celebrated by travelers. This is therefore the highest land of all southern Asia: from there on all lands lying to the south start to tilt toward the tropics, benefitting from the (p. 24) southerly winds of that zone. Here start mountains which cross Persia westward, the two peninsulas of India southward, and China eastward. In the southern valleys of this ancient land, one must look for the first home of the human race and of white men (7) who from (p. 25) there populated in entire nations the prosperous lands of China, Persia, and in particular India. According to a general agreement among all nations, the inhabitants of India were the first civilized people where we may perhaps look for the root of the first languages both of Asia and Europe. Even the people from Tibet, (p. 26) one of the highest lands in Asia, claim that they initially descended from some kind of ape who first lived in this land (they have indeed some resemblance to apes). According to their tradition, Tibet owes the refinement of their manners to teachers from India (p. 27) and was until then perhaps merely a colony of India because early Indians had moved there during the beginning of these uncivilized times. Thus most peoples from Asia, nations that settled later in Europe and on many islands in the south of Asia, apparently originated from the heart of this continent. (p. 28)

When searching for the source of the great rivers which cross Siberia and flow into the Arctic Ocean; of rivers which join the Amur and flow into the northern part of the Sea of Japan; and of the waters which run westward toward the great lakes in the middle of the desert of the Tatars, of which Lake Aral (p. 29) is the largest, we find above the springs of these rivers the continuation of the Altai Mountains. All Asian nomads concur that the highest part of the northern Asian Mountains is the mountain called Boghdo (the highest) which used to form the natural boundary between the enemy hordes of the Kalmucks and the Mongols. The peaks of this mountain reach far above the snowline and the top of all other mountains of northern Asia. (p. 30) From there branch out two great and two medium chains as from a common center. The one that goes south, called Mussart, joins the mountains of the Tibet. A smaller chain, called Alak (8), runs westward, spreading

in the deserts of the independent Tartars or Kirghiz and of Bukhara, joining secondary chains which are connected both with the extremities of the Ural Mountains and of the great mountain (Ulu-tau) which takes up the middle of the Kirghiz desert and eventually disappears toward the Persian mountains. A third chain called Khangai heads straight east between the land of Ortus or Barkol and Mongolia; it fills the latter with cliffs and high mountains and separates the Amur from the Choango (or Yellow river) under the new name of *Khingan*. This chain finally ends (p. 31) in the downward curved chain forming Korea and the island arcs toward Japan.

Finally, the third [fourth] and major mountain range, known by the name of Altai, forms the frontier of Siberia between the rivers Irtysh and Amur. Its highest peaks are outside the Russian Empire. From the high Boghdo Mountains, the Altai stretches over the sources of the Irtysh to the Ob, forming in between an angle with very steep and snow-covered mountain peaks where the main chain is surrounded by schistose rocks which at some places are pierced by granite. There is located the most important mining district of the Russian Empire, today extremely rich in silver ores with gold, in the future even more promising, and with respect to the copper mines, whenever they will be used, inexhaustible. From there the great range stretches to the Lake Telezkoy, or Altayn-Noor, where the river Ob as well as many (p. 32) other rivers and brooks originate. The range then seems to retreat to inclose the great rivers which flow into the Yenisey. From there, high and mighty chains continue toward Lake Baikal under the name of Sayan. Although this first range of granitic mountains, which forms the natural frontier of the Russian land, is extremely high and has several snow-covered peaks, the course of the rivers flowing into the Yenisey and Selenga show that the watershed lies yet beyond these mountains. Indeed, above the sources of these rivers, one finds, besides the general elevation of the land still a higher chain parallel to the first one. It consists of a principal branch of the Khangai which runs partly between the sources of the river Tschikoy and the tributaries of the river Amur. After its union with the first branch of mountains which surrounds Lake Baikal, it continues as a powerful chain (p. 33) named Stanowoy Khrebet and crosses the farthest eastern part of Asia. We shall return to this range after a detailed description of the space between the great chains mentioned above and the high mountains of the Tibet.

According to travelers, especially those who often accompanied Russian caravans to Peking, there is no doubt that this vast desert, which stretches from the frontiers of Tibet to the region of Nerchinsk, called Gobee or Schamo [Gobi desert], is certainly one of the highest plateaus on Earth, comparable only to the high plains at Quito. (9) A large part of the Mongolian (p. 34) desert and the plains between the Altai Mountains and the one I have called Changhai, as well as many smaller plains and flat valleys which exist in the middle of these mountains and their branches, are about at the same elevation above sea level and the general flat plains. If one

travels to Peking, one sees from the frontier of Selenginsk, which is at quite considerable elevation, a steady rise of the land toward the mountain of Chan-oola. One has to climb this very steep mountain to reach finally, almost without descending, the vast Gobi desert, a similar plain without trees, with a few hills, some salt lakes, and very few springs which immediately disappear into gravelly ground. From the Gobi desert, travelers descend through narrow passes and very steep slopes toward the Great Wall from where the land still slopes further toward the plains of Peking. Similar high plains, covered with gravel and pebbles — among which one finds beautifully colored stones — (p. 35) are probably the result of weathering and disintegration of the very old granitic rocks. These are the sites of the lakes Balchash, Lob, Kokonur, as well as a great number of smaller reservoirs which collect here and there the waters from the surrounding hills which have no other outlet through valleys.

The extraordinary high elevation of all these deserts is proven by a gradual step-like rising of the mountains which surround all of Central Asia, where all the great rivers originate that cross this continent much below the said great plains, yet high enough above sea level for a sufficiently rapid flow necessary for their long course. This high elevation is also confirmed by barometric observations of Jesuit missionaires and other travelers to these regions as well as by the cold climate, even in summer, in a temperate zone. Moreover, all the lowest valleys in these mountains which form both the border and the steps to these high watersheds (p. 36), grow creeping bushes and other creeping plants which are proofs of the very high elevation. It is common knowledge that European Alpine plants grow well in the plains and valleys of Siberia, in particular in those close to the great mountains. More unusual, the beautiful plants and bushes, typical of Siberia, and so much in demand by foreign experts, occur only in the neighborhood of the Altai Mountains and their eastern offshoots. Various animals which dislike plains and hence are less prone to propagate, such as the buffalo with a horse tail, the tiger, the sable, the reddish-brown polecat, the muskrat, the mountain rabbit, etc. have remained in the mountains of Central Asia. In these high elevations the theory of corresponding angles in mountains of the philosopher Bourguet [16], repeated by Count Buffon, cannot be proven. This theory encounters many exceptions in all granitic mountains (p. 37) and even in those of secondary order.

Here we have thus a vast stretch of land crossed by mountains which lies infinitely higher than the plains of the Asian continent itself. It extends over various climatic zones and provided excellent conditions during the first eras of the world for the survival and development of northern and southern produce. If one supposes (and based on reason there ought to be no doubt about it) that the general level of the sea was once high enough to cover the horizontal layers [*Flötzlager*] of the land, today filled with marine organisms, then Central Asia must have formed in the past a vast island surrounded by mountains, with as many promontories and island arcs as there

are today mountain chains spreading from the center. If we suppose, furthermore, that this high plateau consisted at first merely of pure granite, its decomposition by daily erosion and weathering provided soon (p. 38) great amounts of coarse sand (10), decayed rocks, and clay, materials that are found everywhere in mountains and which prove to be extremely fertile for (p. 39) growing all kinds of vegetation. The chain which stretches, as we have said, between the springs of the rivers Onon (p. 40) and Ingoda on one side, and Tschikoy on the other, and which is accompanied by very high mountains, continues without interruption in a north-east (p. 41) direction, separating the waters of the Amur from those which flow into the Lena and Lake Baykal. This chain sends a branch of mostly schist-like mountains along the river Olekma — which crosses the Lena above the city of Jakuzk — and continues between the two Tunguska rivers until the Yenisey where the chain disappears in the swampy and forested plains which occupy the entire space west of Yenisey as far as the Ural Mountains. Further on, the eastern principal chain, rocky and jagged, approaches the coasts of the Sea of Okhotsk, passes very close by the springs of the rivers Uth, Aldan, and Maya, separates into several branches which extend between the eastern rivers which flow into the Arctic Ocean, and reaches the final destination in two principal branches. A continuation of this chain curves southward, crosses the entire length of Kamchatka and reaches (p. 42) Japan by means of the Kuril Islands. This chain gives the entire land of Kamchatka a very steep and rocky eastern coast which lies opposite to another chain of recently discovered islands.[17]

This mountain-range [Aleutians Islands] has many volcanoes as Kamchatka itself, traces of which have all but disappeared in the interior of Siberia. (11) The other main branch (p. 43) forms the great Chukchi peninsula with its promontories and rocky coasts. It seems to join through the so-called St. Andreas Islands a mountain chain which runs through the entire opposite American continent. The direction of this chain (which, as much as we are informed, is parallel to the position of the coast, that is, from the north-west to the south-east) completely refutes the strange discoveries known under the name of *de Fuca* and (p. 44) *de Fonte*. (12) Nevertheless, it is certain that although the northern promontories of both continents are converging, their distance from each other is still greater than normally assumed, but infinitely much smaller than accepted by those who are in favor of a north-eastern passage.

I have mentioned earlier that the bands of schists which everywhere on Earth are associated with granitic chains, consisting of *reinem Sandfels, vermischten Feldsarten, Horn-und Thonschiefern, Spath-und Hornsteinarten, Porphyr und Jaspis vermischt* (pure quartzose rocks, mixed rocks, horn-and clay-schists, marbles and serpentines, porphyry and jasper), that is mostly of rocks which occur in almost vertical or at least highly tilted layers, are, like granite, older than the creation of organized beings. This statement is strongly supported by the fact that in most (p. 45) of these rocks, even if they split like shales of the *Flötzgebürgen* (and are hence most

favorable for the infiltration of water and production of springs), these bands of schists have never displayed the slightest trace of petrification or imprints of organized bodies. If some were actually found, they probably occurred in fissures where these bodies were transported by a flood, where they were then surrounded by infiltrating matter and later petrified just as one finds remains of elephants [mammoths] in veins or mining shafts in the Schlangenberg silver-mine [today Smejnogorsk, in the Altai]. Characteristics like mighty veins, fissures, and pockets of the richest ores that mostly occur in the said band of schists; the position of this band immediately upon granite; and even the gradual transition often seen on a large scale in granite when it changes into some of the other rock types, all these characteristics seem to show that many of these rocks are the effects of a violent fire. They point to a (p. 46) much older beginning and to effects which did not exist during the formation of younger mountains.[18]

The mutual arrangement found among the most common rock types in the band of schists seems to be quite uniform in all the mountain systems of the Russian Empire. The Ural Mountains, for instance, have on their east side, throughout their entire length, a great abundance of horn-, serpentine-, and calcareous schists which are rich in copper veins and are followed by rock types that are closer to granite,[19] as well as in jasper of various colors that occurs more downwards and is often interbedded with the above-mentioned ones, but generally forms by itself entire mountain ranges and vast regions. On the same side we find great masses of pure quartz, both in the principal chain and in the heart of the jasper formation, even in the plain. Marbles with feldspar or other minerals crop out at several places. Most of these rocks do not occur on the west side of the Urals (p. 47) where only sandstones as well as argillaceous, alunite-bearing, and inflammable [bituminous] shales occur [*Thon-Alaun und brennliche Schieferarten*]. Whereas the eastern schistose band is rich in gold veins mixed with other ores, has plenty of veins and stockworks of beautiful copper ores, and vast pockets and entire mountains filled with rich and magnetic iron ores, the west side has merely some iron ores and ferruginous mudstones [*Moraststein*] and is generally very poor in metals. On the side of the Altai Mountains that is known to us, granite is immediately covered by *Hornfels* [hornstone, schistose metamorphic rock, used in a wide sense] which is often very similar to a very fine sandstone and becomes associated with very metalliferous schists of various composition. In the Altai, jasper is found only in veins whereas there are only few examples in the Ural Mountains. These veins abound in Siberia with the exception of that part of the principal mountains which trends close to the Sea of Okhotsk where jasper forms entire mountains as mentioned in the Ural Mountains. However, these rocks occur on the south side of the Siberian mountains, an area which we do (p. 48) not know in its entire length, so that jasper might perhaps also be plentiful there. Much more observations and mining-works are required to give a better understanding of their order and their variation.

I am more certain about mountains of second and third order in the Russian Empire, namely layers of limestone, and layers of sand and marl deposited later above limestone.[20] Based particularly on the nature, arrangement, and composition of these mountains, as well as on the great dissimilarities and the shape of the European and Asian continents in general, it is possible to reach some more reliable conclusions on the changes that have occurred in the lands now inhabited. These mountains represent the oldest history of our Earth which is just as unfalsified — though more readable — than the indistinct monuments found in the old primitive mountains. These two orders of mountains represent the archives of Nature which existed before the invention of the alphabet and even before the oldest legends. It remains for our century (p. 49) to examine them more closely, to analyze and bring to light any small detail, although several centuries after ours, the task shall probably be left unfinished.

Careful observations everywhere in the Russian Empire, as well as in Europe, have shown that in general the schistose band in great mountains is immediately followed by limestone mountains. These consist of two kinds which differ widely from each other with respect to the elevation of mountains, the position of the layers, and the nature of limestones. This difference is particularly striking in limestones which form the western border of the Ural Mountains and then spread all over the flat land of Russia. The same could perhaps be noticed on the east side of the chain and everywhere in Siberia, but the horizontal limestone beds (p. 50) are there covered by later deposits so only the most protruding parts of limestone beds are visible at the surface. (13) However, this land has been inhabited only for a short time and little research has been done to reach any valid judgment on its nature. What I shall mention hereafter on the two kinds of limestone mountains concerns particularly those which lie west of the Ural Mountains. Nothing but solid limestone mountains are found there over some 50 to (p. 51) 100 versts [1 verst = 1067 m] whose rocks are of uniform grain, often without any traces of marine productions, sometimes just a few shown by some scattered imprints. These rocks rise to mountains of considerable elevation. They are disrupted, precipitous, and cut by steep valleys. Their uniformly thick layers are not horizontal but steeply dipping; they run mostly (p. 52) parallel to the direction of the mountains which is usually the same as that of the direction of schistosity in schists [*welche auch gemeiniglich die Richtung der Ablösung in den Schiefern ist*][21], whereas on the east side of the Ural Mountains, limestone beds are on the contrary at a more or less right angle with the direction of the mountain chain.[22] In these high limestone mountains exist many caverns and caves of strange appearance, both in regard to size and to their crystalline stalactites. Some of these caves seem to have been formed by the disruption of beds, others by underground springs which softened, eroded, and transported some soluble part of limestones.

At some distance from the Urals, the limestone beds flatten rather suddenly, taking a horizontal position, and become rich in all kinds of shells, madrepores, and

other marine bodies. Such beds are found everywhere in the lowest valleys at the foot of the mountain (p. 53) (and also close to the river Ufa). The same limestones spread all over Great Russia, in hills and in plains, now very rich in marine fossils, now consisting of broken shells, madrepores, and calcareous sand — such as is frequently found in coral-rich coasts — now these beds are replaced by chalk and marl, often interbedded with layers of gravel and rounded pebbles. As soon as one abandons the swamps of Ingerman [N. W. Russia between Volchov, Narva, and the Bay of Finland] which form some kind of bay full of lowlands toward the Baltic Sea, and starts to climb toward the elevated land of Russia, bordered by the Valdai Hills, one encounters everywhere old remains of the sea. First a ground dissected by deep valleys and ravines which evidently seems to have suffered from a very violent flood, or rather from the powerful discharge of an enormous mass of water. Then we find these traces in entire beds of limestone which must have been deposited by a calm sea that has remained for a long time in these areas, (p. 54) limestone which now has become exposed by rivers. In the first disrupted areas, one finds irregularly deposited layers of earths, scattered with small and large pieces of granitic rubble detached from their original mountains; huge banks of rounded pebbles and coarse sand, associated with a few fragments of limestone; petrifications either broken or changed into flintstones; and even animal bones. A similar disruption of older layers, in particular of limestones, has been observed as far as Lake Onega where a branch of mountains from Lapland and Sweden starts to rise. The same can be observed in all the countries close to the Gulf of Finland where less solid layers, which rested on hard rocks, were partly removed. It suffices to look at the map to see in the many lakes between the Gulf of Finland and the White Sea, in the islands, the cliffs, and the broken coasts of this gulf, the effects of a marine (p. 55) flood that drained in that direction. The conclusion of this essay suggests that the Baltic and the White Sea themselves — these great embayments into the land — can be considered as the effects of this powerful flood.

Farther inland, where limestone layers are less disrupted, one becomes entirely convinced that these layers, now thin, now thick, that form hills either separate or connected in small rows, were deposited at the bottom of a deep sea, as were layers of clay which are found everywhere underneath the limestone layers and are also filled with marine productions. These two rock units once formed the bottom of a deep sea which brought forth all the initial marine bodies, for they are never mixed with any remains of terrestrial animals. It is obvious that these deposits required many many centuries. This is particularly true for clay, whose thickness has not been (p. 56) estimated as yet and which, in my opinion, seems related to part of the schistose band in high mountains. Nature certainly needed many centuries to produce this rock unit. Its kinds of petrifications, moreover, prove that the sea that covered them was very deep. (14)

In these layers of clay are found the greatest reserves of pyrites which were pro-

duced at great depth from the raw materials of the decaying components of many marine organisms (fish, zoophytes, and sea plants) for (p. 57) we find sea shells covered by a crust of pyrite and welded together, as well as masses of pyrite which could have been formed only by the waves of the sea. Pyrites are so abundant in certain black shales and claystones that they are sometimes forming a greater volume than claystone itself. This overabundance of a mineral which becomes inflammable if exposed to humidity, together with enormous layers of coal-like [bituminous] shales, usually interbedded by clay strata, leaves no doubt about the cause of volcanoes, (p. 58) in particular those which often erupt at the bottom of the sea where all these materials are accumulated. These facts confirm the generally accepted theory which, after so many concurring observations, has become more than a mere hypothesis. [23]

Based on the observations of limestone and clay-beds, it is evident that all these plains which became the fatherland of the mighty Russian nation; the seedbed of heroes; the last refuge of sciences and arts; the stage for the deployment of marvels by the vast and creative genius of Peter the Great; a place where his great successor [24] brings happiness to millions of her subjects, represent a model to be respected by all the kings of the world and to be admired by all people; I say that all plains of Great Russia were once a sea floor. However, granitic mountains, ridges, and high plateaus, as I have mentioned earlier, (p. 59) were never covered by the sea — of which there are no traces — as believed by Count Buffon. These plateaus and high mountains have always been islands or dry land, although smaller than our present continents, but habitable for terrestrial animals and plants. We have yet to find the causes that lowered the former sea level to expose these vast stretches of land that today represent the plains; we must explain how these enormous banks of marine shells were changed to dry land, and how some were lifted to form mountains of such elevation which makes us doubt that they were indeed produced at the bottom of the sea. I believe that one should combine the general effects, observed in all the countries of the Earth, of volcanoes and other underground explosions, with those of one or several huge floods or overflows of the world-ocean, to give some plausible reasons for all the changes which undoubtedly have occurred on our globe. It is necessary (p. 60) to put together several modern hypotheses and not refer only to a single one, as practiced by almost all authors of theories of the Earth.

Before giving such a composite hypothesis, that ought to explain the most astonishing observations of the present state of the Earth, I must speak about a third kind of layers [*Flötzgebürge*] which are noticeably younger than the fossiliferous layers on which these younger beds rest. Until today, such an important succession of layers as those which occur immediately west of the Ural Mountains, along their entire length, has not been observed elsewhere. I call them mountains of third order. They were caused by the most recent changes on Earth.

These deposits, consisting mostly of sandstone, reddish marls, interbedded by rocks of various composition, form a chain of lower mountains (p. 61) which are everywhere separated by a valley of various width from the just mentioned higher limestone-mountains. Frequently cut by canyons, these mountains rise to a vertical height of 100 fathoms [600 feet] and spread toward the plains of Russia in rows of hills which separate rivers, generally accompany the northern or western bank of rivers, and finally are transformed into piles of sand which cover vast regions and spread particularly in long bands parallel to the most important streams. These mountains of third order are highest when closest to the main chain, through the governments of Orenburg and Perm. There they consist essentially of *Sandschiefer* [arenaceous shales] and are rich in sandy, clayey, and copper ores which occur commonly in horizontal beds [*Flötze,* that is, bedded copper ores instead of veins]. Further toward the plains, run a series of marl-like hills which contain as much gypsum as the former contain copper ores. I shall not give more details on these hills (p. 62) other than mentioning that gypsum points to the presence of salt springs. Mountains of *Sandschiefer,* however, which occur most frequently and form the highest elevations in the Russian plains — even the high plains of Moscow — contain very few traces of marine organisms, at least never entire heaps such as found in limestone beds which were deposited by a calm sea that stood for many centuries above a sea floor. However, in the layers of *Sandschiefer* that are piled up above older limestone beds, nothing is more abundant than entire tree trunks and pieces of wood, petrified and partly mineralized by iron and copper, imprints of trunks of palm trees, of plant stems, of reed, and of exotic fruit, and finally bones of foreign land animals which are so rare in limestones. Petrified wood is also found in sandy hills in the plain, as for instance in those of Syzran on the Volga, where it has been changed into a very fine whetstone which has preserved the organic texture of wood. This wood is particularly noteworthy for the precise traces of sea-worms which attack (p. 63) ships, piers, and other woodwork in sea water and actually originate in the Indian Ocean.

In such layers of sand, mixed or interbedded with clay and marl, one finds the remains of great animals from India, bones of elephants [mammoths], of rhinoceros, of enormous buffaloes [bisons]. These remains are excavated in our country everywhere in such quantity that many naturalists came to admire them. In Siberia, remains of foreign animals are found almost along every river, and even fossil ivory — in excellent condition — occurs in such abundance that it became an article of trade. The uppermost and most recent layers of sand and marly soil serve as tombs in Siberia, and nowhere are these strange monuments more frequent than in places where the great mountain, which stretches along the entire southern Siberian border, offers some lower passes or appreciable openings. (p. 64)

These bones, now spread around, now forming entire skeletons in huge heaps, must convince anyone, who has seen them in their natural sites, of the reality of

an inundation, of a catastrophe which has occurred on Earth. I must confess that I was questioning the truth until I traveled to the places where these monuments are found and saw with my own eyes all that can serve as proofs for such strange phenomena. (15) The infinite number of these bones in sand layers, associated with small calcinated Tellins [freshwater clam with a calcareous shell], fish-bones, shark teeth (glossopetris), wood mineralized by ocher, etc., prove that these remains were transported by floods. However, the skeleton of a rhinoceros with its entire skin and some remains of tendons, hinges, and cartilages, buried in the frozen soil [permafrost] close to the river Wiljui that flows into (p. 65) the Lena (of which I sent the well-preserved head and one foot to the Cabinet of Natural History of the Academy of Sciences at St. Petersburg) serves as undeniable proof that only the most violent and sudden flood could have transported this dead body to these cold climates before any putrefaction of the soft parts had time to set in. We hope that some future observer will reach the area between the rivers Indighirka and Kowyma [Kolyma in N-E Siberia] where, according to some hunters, similar skeletons of elephants [mammoths] and other gigantic animals, still covered with their skin, are apparently found quite often.

After having given the major observations made in Russia that might help to advance research in the natural history of the Earth, may I be allowed to add a rough sketch (p. 66) of a hypothesis which I believe might explain the present state of the Earth's surface.

Let us assume that the high granitic mountains were always islands above the level of the sea and that decomposition of granite produced the first accumulations of quartzose and feldspathic sand and micaceous clay which are the ingredients of the sandstones and *Sandschiefer* in the old chain. The sea then washed toward the shores of the lands the light-weight, inflammable, and iron-rich material produced by the many decayed animals and plants which inhabited the sea, as well as the remains of these bodies. This material infiltrated [*einseigen*] the layers deposited above the granite and formed great pockets of pyrite, the main cause of the first fire-spewing mountains which erupted gradually in various parts of the world. These old fire-spewing mountains — most of which, including their traces, may have disappeared during countless centuries — disrupted the first solid layers underneath which the eruptions occurred (p. 67). The material of these layers melted and burned under the effects of violent fires and produced most rocks of the band of schists which corresponds partly, and may be connected to the layers of sand and clay in the plains. A similar relation seems to exist between the steeply tilted limestone layers, which are essentially without fossils, and the beds of limestone in the plains. [25] From these times date some of the caves and fissures which cut through the rock layers in various directions. Later, infiltration of quartz, feldspar, clayey and inflammable minerals into these fissures and caves produced the various ores, representing today the so-

called *Stockwerke* [stockworks], *Nester,* [pockets] *Trömmer* [breccias], and veins in our mining districts. Volcanic activity has continued until today, in particular close to and at the bottom of the sea. (p. 68) Thus new islands rose from the bottom of the sea and the same forces probably lifted the enormous calcareous Alps of Europe, which were certainly earlier coral reefs and beds of shells as found in present seas which favor the production of limestone. In the seas, much pyrite must always form in the layers of fat clay underneath limestone. Through accumulations of limestones and precipitation of clay, that occurred naturally below limestones, the bottom of the sea continuously increased. Beds of limestone, piled up here and there in various heights, enclosed a greater amount of either this or that kind of organisms, according to whether an area was more suitable for their creation, or whether marine currents transported other kinds in greater number to a certain place, as can still be observed on the seashores. The waters would always transport lighter and finer material back to the coasts. Elsewhere, various types of earth produced from the mountains, either by decomposition of granite and (p. 69) other stones, or by decay of animals and plants, as well as by rubble detached by streams, fostered a gradual increase of flat lands and hence pushed back the sea by the spreading of the coastal land. Moreover, the sea had often been driven out from large areas by the outbreak of fires at their bottom and the resulting throwing up of mountains and plains. Nevertheless, this diminution of the sea, as well as the probable general decrease and wasting of water on Earth, could not in a million years lay dry all the horizontal marine layers that we admire in the fossiliferous *Flötzgebürgen,* found today far away from the sea; nor could our land have reached its present size. Therefore, a considerable amount of flat land must have existed at the foot of our ancient mountains, richly inhabited by animals and covered with forests, when violent upheavals occurred on Earth caused by gigantic volcanic eruptions in the deepest sea. Waters were lifted and chased to cause enormous floods (p. 70) over great parts of the already inhabited lands while comparatively high mountains were formed [26] and solid land was mixed with these roaring floods and became covered with their deposits. It is possible that immense abysses opened in the interior of the Earth and swallowed part of the waters of the ocean (16) [27] so the general level of the sea reached that known during human history.

This idea, which is not new, has appeared improbable to some naturalists; however there is no other cause, unless we base it on the wrong assumption that the sea covered the highest mountains in the past. Such an assumption, as I mentioned earlier, is incompatible with the present state of primitive (p. 71) mountains. The amount of water required to cover these heights could not have found enough space in the interior of the Earth, even if assumed that it was full of caverns. I believe that the sea covered merely the calcareous stratified hills in the plains which are never higher than 100 fathoms above the present sea level. The calcareous Alps which exceed this elevation must all have been uplifted by the effects of underground eruptions.

Since I believe that in the past the sea stood very high on our planet, it is very probable that it was swelling even more because of enormous submarine eruptions, and perhaps by other natural causes which accompanied these eruptions (for instance, great hurricanes and the sometimes related effects of the tides) so that the sea actually covered (p. 72) the then inhabited plateaus which, because of their resistance, increased the raging power of the enclosed sea even more. Have we not enough examples which show that normal tides, with an average height of 15 feet, can reach 50, 100, even 200 feet by compression in narrow straits, by the resistance of dry land, or by other obstacles? — or (to go from a small cause to a large one) have we not seen the waters of the Neva rise (17)[28] because of winds (p. 73) from a certain direction, increase in few hours by three yards, and flood the city (p. 74) of St. Petersburg, causing damages which seem out of proportion (p. 75) for such a small cause in comparison with the violence of marine floods? Have we not witnessed more (p. 76) recent examples of terrible marine floods caused by earthquakes in Peru and Kamchatka? (18) (p. 77)

Based upon the observation of imprints of ferns and other plants from India in European shales, Jussieu drew the reasonable conclusion that the inundation that transported them into these shales must have originated in the south or the Indian Ocean.[29] This direction is proven by the remains of terrestrial animals which are piled up in the northernmost lands but can live only in the tropics. Therefore, if traces of great underground fires and eruptions can be found in the Indian Ocean; and if causes which are powerful enough to produce such a general flood (p. 78) are present; if the traces of the flood produced by these causes coincide with the direction of a mass of water chased in all directions from this particular area of the sea, then our hypothesis will gain new strength by this point. Indeed, what is better known than the frequency of volcanoes and their remaining traces in all the islands of the Indian Ocean, from Africa to Japan and down to the most southern latitude known today? Volcanoes that still erupt in these regions are the most powerful on Earth. Most naturalists who have described the physical geography of the Earth agree that all these islands are built upon the enormous vault of a common and vast furnace. The first eruption of these fiery abysses which lifted the bottom of a deep sea and produced, perhaps in one or several rapid successive jolts, the Sunda and Molucca Islands, part of the Philippines and the southern islands, (p. 79) had to chase from all sides an amount of water that surpasses our imagination. This flood in pushing northward toward the connected mountains of Asia and Europe, while increasing further by a succession of new floods, must have caused enormous destruction and breaches in the lowlands of these countries. It must have torn off formerly deposited beds as well as the uppermost soft layer of land. After having conquered the lower areas in mountains of average altitude in Central Asia, the flood must have dumped in layers, on the slopes beyond this part of the world, all the materials with which the eruption had originally filled the sea waters, in addition to the mud ripped off

by the flood. The remains of trees and animals, involved in this upheaval, were buried in great disarray together with other materials. Their superposed deposits represent today's layered mountains of third order, mentioned above, that fill the entire plains of Siberia. This northward rushing flood must have finally mixed with the great masses of oceanic water (p. 80) that were still covering the plains. But during the general diminution of the sea (through the then opened abysses) and its running off toward the North Pole, these waters must have carved the uneven surfaces of the ground: the valleys, the river beds, the lakes, and the great bays of the Arctic Ocean. At the same time, older layers were disrupted and enough mud was carried off filling some parts of the sea floor in the Arctic Ocean thus forming its shallow coastlines.

It seems more reasonable to consider the large ocean bays in the south of Asia produced either by the irruption of the sea, or its partial retreat,[30] rather than by the imperceptible effects of a general east-west movement of the sea, as maintained by Count *Buffon* (Vol. II, p. 114 ff). Thus could be explained, at the same time, all other irruptions of the (p. 81) sea that would indicate the direction of the flood, as well as its origin that we assumed to be in the Indian Ocean. Indeed, the Sea of Okhotsk and Penshinsk, the Persian Gulf, the Red Sea, the Mediterranean, the Adriatic and Black Sea, the Caspian Sea, the Baltic Sea with the Bay of Bothnia, and the White Sea, which are among the most important embayments on Earth, cannot be attributed to that westerly movement of the ocean because that movement goes into so many and often opposite directions. According to our explanation, one can see a possible cause for the large promontories of Asia that all point south, and the reason why the southern inclined surface of this continent, counting from its highest mountains, is narrower than the northern slope, and why the slope of South America, east of the Andes, is much wider, than on the west side. The waters of the flood must have eroded these continents upon invading them, (p. 82) carrying away the soft layers, and increasing the plains on the other side of the mountains with deposits of layered beds. And by what miracle should Africa, which has no bays on its eastern coast, have been spared — as mentioned by Buffon — from the destructing effects of the western ocean currents if this almost imperceptible movement was in fact effective? Why should this continent not have suffered since it lies entirely in the tropical zone where the general currents are strongest? The regions where this famous author saw remains of a former continent engulfed by the sea, ought to be called with better reason (even in America) newly born lands which were recently uplifted because of eruptions of fire at the bottom of the sea.

We would then have a plausible natural explanation of the so-called Deluge, mentioned by almost all the ancient civilizations of Asia from Chaldea, Persia, India, (p. 83) Tibet, and China who have all established the time of this event, with a small difference in years, to coincide with the Mosaic Deluge. Europe and the lowlands of Asia have since then undergone considerable changes by other floods. These were sometimes caused by similar eruptions on the sea floor, or by sudden overflows of

large Mediterranean Seas (as the one which still bears this name) and the Black Sea (19) which, after draining, left behind vast swampy (p. 84) plains; and finally by invasions of the sea and flooding of lowlands which had formerly been protected by natural dikes. I shall not mention here the effects of smaller single volcanoes from a shallower sea, nor the washout of layers by tempestuous mountain rivers, the effects of earthquakes, winds, waters, and the increase of land by the decomposition of plants and animals, and so on. These details would lead too far and would tire (p. 85) the patience of my readers, all the more that these details are mentioned sufficiently in various well-known works.[31]

Finally, I do not wish to claim that my hypothesis should be praised as entirely free of difficulties because it is based merely on what various famous authors have thought individually about this matter. Nevertheless, I dare to maintain that Nature uses obviously a variety of processes to create and destroy layers of rocks and change (p. 86) the surface of the Earth so that any hypothesis that is based only on one or a few of these processes cannot give a satisfactory explanation. However, if one combines and approaches all the processes and effects of Nature, of which human history and in particular the great book of Nature itself have preserved the monuments, then one comes closest to the truth. And that is the only degree of perfection that one can ever expect from hypotheses which can never be presented as proofs. It seems to me that one cannot think of a more natural cause than the one I have presented to explain the general flood as well as several minor ones which are recorded in the oral traditions of peoples. This hypothesis, nevertheless, is not capable to bring a flattering promise of a quiet life of pleasure to people who inhabit these fertile plains. Indeed, the (p. 87) small effects of the eruption of volcanoes in certain areas of the sea, of which history has preserved so many examples, and of which the present has seen the sad consequences, must necessarily awaken fears that even worse catastrophes, fatal to the entire hemisphere, must occur in the future. Happy will be those who live in the mountains whose apparent unfavorable lot has placed them in those regions. They will provide the new seedbed of the human race; they will be able to conquer the plains devastated by floods without bloodshed.

PALLAS' FOOTNOTES

1. (p. 5) Histoire naturelle ed. 12. Vol. I. p. 128.
2. (p. 6) (Idem) p. 111.
3. (p. 6) (Idem) p. 116.
4. (p. 6) (Idem) p. 164.
5. (p. 13) *Count Buffon* himself admits (vol. II, p. 35) that the peaks of the highest Alps [mountains] that he has seen, which measure often 200 or 300 fathoms from top to bottom [1200 or 1800 feet, these "Alps" are therefore obviously only small mountains in Buffon's neighborhood], are usually rocks composed of different kinds of granite. Elsewhere he writes that such rocks never contain any shells. This contradicts what we said about him above. He is not more correct when he places granite among rocks deposited in layers (vol. II, p. 27). I admit that certain granites seem to occur in layers of several feet.

But fissures that separate these rocks into large parallelipipedic masses (p. 14) prove no more that granite was formed as sediments in water than would articulations in basalts or cracks in a clay hardened by fire. A clear evidence against the view that granite was precipitated in water is the enormous rock chosen by the noble successor of Peter the Great to support the monument of his great predecessor. The measurements of this huge rock (21 foot high, 36 long, and 21 wide) contradict the above concept because such a massive piece of rock, weighing more than 3,200,000 pounds (all together believed to weigh 5 million pounds before transportation) could never been found anywhere on Earth as layers formed by water.

6. (p. 7) The *Abbé Chappe d'Auteroche* [Voyage en Sibérie, 1768] was correct in contradicting *Ysbrand Ides* and *Lange*[1] in regard (p. 18) to the excessive elevation attributed by these travelers to this part of the Ural Mountains, between Solykamsk and Werchoturje. One may also excuse Abbé's assumption that Siberia, or the plains east of the Ural, are lower than those in Europe, contrary to *Strahlenberg's* opinion[2]. The northern regions, where he traveled with a superficial mind for observations, are indeed lowlands covered with forests and very often by swamps. Nevertheless, he admits that the Siberian plains rise noticeably toward the south, that it toward the Alps [high mountains] which form their border. Since this great mountain chain spreads more and more eastward over Siberia and rises simultaneously, the elevation of the Siberian plains increases considerably and the slope becomes steeper: this justifies Strahlenberg. This inclined plane sloping toward the North Sea exposes Siberia to the north and north-easterly winds while the warm south winds are intercepted by the great chain at the border, whose highest peaks are covered by eternal snow whereas winds from the west are cut off by the Ural Mountains (p. 19). These are the main reasons for Siberia's harsh climate; they are certainly more important than its elevation alone or the saltiness of the soil to which the Abbé and others would like to attribute the rigorous cold which reigns there. As proof, I would like to refer to the region close to the foundry at Barnaul [today Krai Altai] on the Ob River which is protected from northerly winds by some screen of mountains and forests between the Tom and Ob Rivers, thus providing a climate warm enough to grow all kinds of garden vegetables in the soil, even melons and squash, whereas 2 degrees of latitude to the south, such vegetables never mature on the slopes of the Altai Mountains which are exposed to the north. Similarly, in the valleys of Selenginsk and the river Abakan, flowers bloom in April at the foot of these mountains whereas their northern slopes are covered with frost and snow until June. Some parts of Europe owe perhaps their mild climates to the Scandinavian and Scottish Mountains which ward off northerly winds and also to the fact that the ice from the north finds a way out between Europe (p. 20) and America where currents transport it to the tropics so that northerly winds are not so cold and longlasting in summer. The icecaps enclosed between Cape North and Spitsbergen, however, influence the climate of northern Russia. The deserts of Astrakhan and Crimea, on the other hand, owe their hot summer, which produces plants that usually grow only in Persia and Syria, to their exposure to south- south-easterly winds and to elevated lands which protect them from the north. Winds from the north-east and south-west, reflected by the Ural and the Caucasus, cause there freezing winters and often cool summers. None of these circumstances compel me to have recourse to the concept of a central fire which is not very useful anyway, because the waters in the ocean depths have not even become as warm as the waters at the surface as proven by observations of temperature at various depths.

7. (p. 24) In spite of what *von Pauw*[3] may have said, the origin of the Negro race by climatic influence is not quite as simple as he and others believe. It is not yet clearly established whether the Portuguese became black in Africa, as the Abbé *Demanet* seems to maintain. The darker skin might rather be the result of sexual excesses of these colonists and of their mixing with natives. Indeed, Mr. *Niebur*[4] mentioned that those "Banjanen" who live and trade in the countries of black people without mixing with the natives, retain their natural complexion [The French version omits Niebur's opinion]. The black semen of negroes has not been proven either, and the *Aethiops animalis,* mentioned so often by Pauw, is merely an occult property and not an explanation. This material must have disappeared long ago among the black islanders in the vicinity of the South Pole, in particular in New Guinea, where it sometimes becomes a reddish wool without any change in the color of the skin. The moors who have lived for many centuries in areas hotter than those of many negroes, have retained (p. 25) the characteristics of a different human race. Since Africa is not connected with Asia by a very high and entirely continuous mountain range, both continents must have formed separate islands during the oldest times of the Earth when the sea level was much higher. The black race might have lived on one of them since unrecorded times and undergone changes produced by its exposure for so long to the influence of the tropical zone or to particular circumstances. [See Saussure's reaction to Pallas "poorly digested" opinion on the origin of the black race in Chapter IV, sec. 8]. It is not necessary to resort to an unusual mixture or bastardization of the human race as might have occurred among the Quimos or the people with long arms in the mountains of Madagascar. One might suppose that the black race represents the main branch of the entire human species and that the white race is but a consequence of degeneration because black animals and birds often turn white, whereas white ones seldom change into black. However, the procreation of white negroes, but never black whites, except some kind of albinos, or overly blond, (p. 26) weak-sighted, or even red-eyed

children, as well as people with skin blotches, would point to the contrary. Furthermore, birds of light or motley color may turn black; and there are truly black ones among the northern hare and the ice-fox, both animals belonging to a species which turns white in winter. It should be pointed out that all domestic animals now living in the northern as well as the southern countries, could be found originally in the wild in the temperate climates of Central Asia, with the exception of the camel, of which two species exist only in Africa, which have difficulties to adjust to Asia. The wild boar, the bison, the wild sheep — from which descends our sheep — the bezoar goat and the ibex — the cross-breeding of the two produced the fertile species of our domestic goats — all had their first home in the mountains of Central Asia and some parts of Europe. Many reindeers live and are (p. 27) domesticated in the high mountains on the border and in the eastern part of Siberia. They live also in the wild in the Ural Mountains up to the 56th parallel from where they have spread to the polar regions. The camel with two humps is still living wild in the great deserts between Tibet and China. In the forests and swamps of all the temperate regions of Asia lives the wild boar. The wild cat from which the domestic cat descends is well known in Europe. Finally, the elder branch of the domestic dog descends certainly from the jackal which is by natural disposition little afraid of men, and hence easily domesticated, and (according to *Chardin*)[5] even trained. The jackal also gets along well with the shepherd dog, as we have seen with the one brought from Persia two years ago. I do not believe, however, that the race of our dog is pure-bred. It must have been cross-bred since unrecorded times with the common wolf, the fox, and even the hyena, and from these cross-breedings we have the great (p. 28) variation in shape and size of dogs. The largest one that came from India at the time of Alexander was probably a product of the hyena. Of medium size among its related breeds, the jackal, when domesticated, lends itself best to breed with other related domestic species. Fertile cross-breeding is without any doubt quite possible since our present domesticated dog breeds quite well with the wolf in England (See *Pennant Synops,* p. 144)[6] and with the fox in Mecklenburg (see *Zimmermann Specimen zoologiae geograph.* p. 471)[7], not to mention the fox-and wolf-dog of the ancients. All these domestic animals are originally from the temperate zone of Asia which seems to prove that the high plateaus of this continent were also the first home of man. The human race may have been transported to Africa by chance (p. 29) at a time when the high plateaus of that continent were still separated from Asia by a vast sea. Because this new land was entirely in the tropical zone, the influence of a hot climate during many centuries must have considerably changed the bodily constitution of these transplanted humans. Meanwhile in America [South America], where settlement by humans seem to have occurred later, a similarly hot location could not result in such striking effects because in a country with a south-north trending mountain chain, these humans were perhaps able to change more often climatic conditions. Moreover, living in various climatic zones, they could intermarry so the effects of the tropical zone were weakened.

8. (p. 30) *Alak-Uela* according to the Kalmucks, *Ala-tau* so called by the Kirghiz, means colorful mountain, a name which describes mountains interrupted by numerous deep valleys.

9. (p. 33) In the center of Africa must exist high plains, surrounded and crossed by high mountains, that are similar to those in Asia and America, which may have served as nurseries for the creation of species. One finds also a great variation of animals proper to Africa which under similar climatic conditions have not yet spread to Asia.

10. (p. 38) [*part of Pallas' theory*] It is difficult to conceive that in the past sand was produced by precipitation in the waters of the sea as believed by some modern naturalists, in particular *von Linné*[8]. I am entirely of the opinion of the ancients who believed that sand originates from weathering and decomposition of rocks, in particular granite. The enormous quantity of this material on Earth seems to support the idea that the interior of the Earth probably consists mostly of granite; it is certain that deeply buried and very old layers of sand and sandstone can be only the product of decomposition of granite in the earliest times. Granite that forms the greatest part of the seafloor must be exposed there to continuous decomposition, enhanced by salts in dissolution. Thus, the ocean basin becomes naturally deeper and provides, at the same time, the most fertile source of sand which is gradually transported by the waves to the shores and by the winds spread over the land. P. *Frisi*[9] who holds that pebbles, gravel, and sand are the first ingredients of the Earth — because his experimental crushing of various stones did not produce any similar material — did not consider natural weathering of most granites. Furthermore, every eroded cliff or every river-bed littered with rounded (p. 39) pebbles and other bed load must convince him of the effects of water on loose rocks. The great sand deserts in the middle of Numidia and Tatar, which he says contradict the theory of the origin of sands in the sea, were probably once partly covered by the sea as I mentioned in the third volume of my travels in regard to the sand formation in the desert between the Volga and the Ural river.[10] Decomposition of feldspathic and granitic rocks at Selengisk, that produced the sands around the river Selenga, proves the origin of such material in the Mediterranean regions as mentioned in detail in the same volume. Even the granitic mountains in Siberia seem to have lost much of their elevation because of local rapid weathering of granite in comparison with the Caucasus and the European Alps.

Almost all granitic mountains in Siberia seem to be huge masses of rocks piled upon each other, rounded by weathering, so that they appear to painters and poets as the most beautiful representation of the labors of giants in piling mountain upon mountain to assail heaven. Such separate masses of granite were not explained by *Bourguet* (p. 245).[11] Count *Buffon* maintains in his *Histoire naturelle* (II, p. 31), that (p. 40) these masses of rocks [*Wacken*] found in the highest mountains originated from layers of sand transported there by the waters without affecting the bed already hardened into stone. How did this ingenious naturalist, if he himself made this observation, not notice that these hard rocks forming the summits and the peaks of mountains, are themselves the origin of sand which they produce at their base and on their surface by the effects of weathering? He admits that granite and very old sandstone never contain any shells, although they are present in sand from which, according to him, these rocks were formed (vol. I, p. 406). Instead of recognizing here a proof that granite does not originate from sand but that the latter is merely a later decomposition of the former, he believes that sand, if pure, cannot change into rocks while I prefer to maintain the contrary. The famous *Wallerius* mentions (*Mineralogy,* vol. I, p. 426)[12] that sand contains all the ingredients of granite, namely quartz, feldspar, and mica. He observed correctly that the enormous masses of granite did not originate from sand. Weathering of granite is certainly accelerated by a salty component (p. 41) in granite itself, in particular in Finland and Siberia. The saltiness of the water and the soil in the high plateaus of Asia can only be attributed to this component of granite which may also have contributed to the first salt in the seas.

11. (p. 42) I am talking here about visible traces of volcanoes such as craters, lava, and other volcanic products, noticed in various regions in Europe. I believe that the schistose and metallic band in Siberia must have also felt the effects of fire-spewing mountains but that distinct traces of them have probably vanished with time. The high mountains of Nagelfluh or *Breccia,* forming a great part of the northern shores of the great basin now filled by Lake Baikal — perhaps also the region of the gold-mines close to Catherineburg [today Sverdlovsk] — seem to show traces of similar natural processes, but of greater antiquity. More convincing traces of volcanic activity will perhaps be found later in other regions of Siberia. *Strahlenberg* has (p. 43) mentioned pumice close to the Yenesey river; however, scoria from former mining-industries induced him into error. I have searched in vain for traces of any volcanoes along this river, in particular close to the mountains. There I found the famous huge mass of native iron ore, now deposited at the natural history cabinet of the Academy, which is by nature very malleable and intimately mixed with a vitrous, yellow, and transparent material. Its origin remains a puzzle because of: 1. its size of nearly 1600 lbs, 2. the purity and malleability of the iron and its intimate mixture with vitrous matter, and 3. an iron-ore-like crust which surrounds the whole mass.[13]

12. (p. 44) To accomodate these alleged discoveries, M. *Buache* had the mountain chains in America turn in a manner which run against all other examples on the globe.[14]

13. (p. 50) This explains at the same time why marine petrifications are so rare in the plains of Siberia and become numerous only toward the coasts of the Arctic Sea where horizontal beds of limestone and marl crop out; why chalk is lacking in Siberia, and flintstones are so rare, whereas they are common in Russia and the rest of Europe. Several observations have convinced me that flintstone is a product of clay when the latter is enclosed in calcareous and iron-rich layers, or infiltrated by certain waters.[15] Moreover, I found some flintstones which were full of holes and channels which undoubtedly served as nests for the ephemeral fly. At (p. 51) some places, I saw all the successive stages in the hardening of black clay into flintstone. I owe some petrifications, called "fungites," which are very common in our country and scattered in the fields together with flintstones. They represent some kind of spheroidal millepores whose surface seems to be completely agatized whereas the inside is friable and calcareous. Such agatized "fungites," when cut into slices, appear perforated as a sieve; some of them with empty tubes display a cross-section that is absolutely identical to a sieve. Some European flintstones that decay when exposed to air and are covered by a chalky crust, must therefore derive from some calcareous clay. Only in the chalky mountains of Southern Russia are similar kinds found in our country.

14. 56) It is possible that ammonites and belemnites, whose archtypes have not been seen, remained unknown because they live only in the greath depths of the sea. Their abundance in clay, immediately below limestone beds, proves this point independently. One has often wondered why petrifications in European limestone mountains ought to originate from the Indian Ocean. This proposition seems to be wrong in itself. Indeed, organisms which we believe to exist only in far-away seas, are mostly the same as those in the northern seas, but they can live only at great depths (p. 57) because they seem to need the pressure of a larger mass of water. Among such organisms are the *Anomiae* (also called *Terebratulae* or *Meerhühner*) [in eighteenth-century French, poulettes], sea lilies [crinoids], etc. Furthermore, the Mediterranean Sea produces on its seafloor most of the marine organisms which we find piled up in our limestone mountains. The reason why the North Sea produces so few of them might be that it became filled with diluvial mud as shall be discussed below. As a result, the sea is very shallow, even far away

from the shores. For the same reason, it produces only few corals because of their need of a rocky bottom at considerable depth.

15. (p. 64) See the memoir published in the 17th volume of the New Commentaries of the Imperial Academy at St. Petersburg.[16]

16. (p. 70) See Hist. de l'Acad. de Paris, 1716, p. 14ff, *Buffon* Hist. nat. vol. I, p. 365ff.

17. (p. 72)[17] Based on observations made until now, it has been established that the floods of the Neva are generally caused by storms coming from the south-west or the west and heading toward the north-west. They occur always during the three months of fall: September, October, and November, when the level of the sea as well as of inland waters is highest, and generally at the time of full moon or new moon. This fact is confirmed by observations made since 1749, and published in the calendar of St. Petersburg in 1774, on the highest floods of this river as soon as it stood at three English feet or more above its normal level. At the same time, unusual low levels were recorded which happened, to the contrary, with easterly winds. The high floods, however, occurred almost always under the above mentioned circumstances. Prof. *Leutmann*[18] (See *Webers* Neu verändertes Russland, part I, p. 126ff)[19] pointed to the same causes for the floods which devasted St. Petersburg time and again. The strangest floods recorded were: 1715, with no date given in *Webers,* all ramparts and banks were destroyed; 1721, November 5, during full moon; in October 1723, also during full moon, the river rose three inches higher than in 1721; 1725, November 16; 1726, November 12, the day after full moon, between 8 a.m. and noon, the waters rose to 3 1/2 *Arschin* [1 *Arschin* = 16 *Werschok* = 71.12 cm] above the normal level, and one and a half quart or 3 decimal inches higher than in 1721; 1727, September 21; 1728, August 3 and November 3; 1729, October 3 and 12, 2 days after the full moon, at 10 a.m. with a heavy storm on the sea; 1723, September 15; 1733, September 6, October 8 and 31, and December 12; 1735, February 26; 1735 in the night between September 9 and 10, during a storm coming from north-west (as recorded) which lasted until noon so that by 8 a.m. all of St. Petersburg was flooded with one foot of water which only disappeared in the afternoon; some floods of lesser strength occurred several times in December of the same year; 1740, September 12, the day of the equinox, the water rose 2 *Arschinen* and 3 *Werschock* [1 *Werschock* = 4,445 cm] above the usual water level; 1752, October 22, a raging storm coming from the south-west and turning toward the west produced a water level nine and a half feet higher than usual at 10 p.m. All the islands and areas of the city, with the exception of the "Stuckhof" and the area toward the Newskisch Convent were flooded with such violence that great damage was brought to the inhabitants. The waters disappeared however soon after midnight. The strangeness about this storm was, as Kollegenrath *Lerche*[20] kindly told me, that on October 25, with strong south-south-west winds, the waters which had remained very high, flooded the adjacent streets, whereas on the 26th, with south-west winds, the whole city was flooded again. But since the storm had turned enough toward the north, the river was one *Arschin* lower than the first time. Finally on November 28, in the afternoon, after the river had retreated on the previous day, a new flood recurred, almost without any wind, that caused great damage to Wassilei Ostrow, and which was probably caused by storms on the sea where the waters had been compressed in (p. 75) the Bay of Finland. — To this mournful register of floods which were so destructive to St. Petersburg, we must add a flood which happened this fall (1777) and which was stronger than all the previous ones. The entire night of September 9 and 10 (that is three days after full moon), a storm raged with great violence from the south-west, and then from the west, while the barometer was extremely low. At 5 a.m. the winds chased the waters of the river over its banks and flooded all St. Petersburg, most of all Wassilei-Ostrow, with incredible speed, drowning some areas under two yards of water, sweeping away hedges, bridges, and houses which were more exposed to the sea, uprooting trees, transporting large loaded carriages into the countryside, or smashing them. This situation would have worsened had not the storm at its height at 8 a.m., when the waters had risen more than ten feet above the normal level, and 1 1/2 feet higher than in 1752, turned toward north-west, allowing the waters to retreat by noon. If the Baltic Sea were exposed to the ebb and flow, the floods in St. Petersburg would probably be even worse and come very close to the spring tides of 50-60 feet measured at Bristol. (p. 76) It is possible that storms occuring during spring-tides in the Arctic Ocean, cause the piling up of unusual amounts of water in the Baltic Sea so that our floods here receive their share from a distance when the winds responsible to achieve this become part of the circumstances. Indeed, according to the newspapers, heavy storms raged in the western Arctic Ocean, and in the north, in the direction of the mouth of the Baltic Sea, right before our great flood this year. Lesser swellings of the Neva in fall, between 5 and 7 feet, have been reported ten times since 1752 in the above mentioned calendar: 1756, November 29, westerly winds caused a rise of 7 feet and 3 inches; 1757, October 16, south-west winds: 6 feet; 1759, October 6, south-west winds: 6 feet, 2 inches; 1762, October 28, south-west winds: 5 feet, 10 inches; 1763, October 8, south-west: 6 feet, 6 inches, and November 28, south-west winds: 5 feet, 4 inches; 1764, from November 6 to 22, with clogged "Baaken": 7 feet, 4 inches; 1765, September 16, no winds: 5 feet, 6 inches; 1772, December 31, south-west winds: 5 feet, 2 inches.

18. (p. 76) A description of the violent earthquakes in October 1737 on Kamchatka and the (p. 77) Kuril Islands followed by a terrible flood and the emergence of a new island between the first and the second Kuril Islands can be found in *Krascheninikow's* description of Kamchatka (Russian edition, part I, p. 271)[21]. The sea bobbed up and down between 39 fathoms of vertical height. *Steller*[22] found on the Bering Island some driftwood — very frequent in that sea — and skeletons of dolphins and whales washed into the middle of the mountains of that island, approximately 30 fathoms above the level of the normal tide.[23]

19. (p. 83) The opinion of the tireless *Tournefort*[24] and of Count *Buffon* on the former state of the Black Sea and its connection with the Caspian Sea is increasingly confirmed by observations of travelers. Seals, some fish and sea shells, common to both the Caspian and the Black Sea, are proofs of this ancient connection. Similar circumstances in Lake Aral prove that it was formerly linked to the Caspian Sea. In the *Third Volume* of my Travels, I have estimated the former size of this sea (p. 84), in particular from the desert of Astrakhan beyond the river Jaïk [Ural], according to the apparent coastlines by which the high plains of Russia surround this desert; the state of this former coast and its fossils, and the calcinated [calcareous] sea shells mixed with salty silts which cover the entire surface of the desert itself. One finds in the *Description de l'Ucranie du Sr. Guillaume le Vasseur Sr. de Beauplan* (at Rouen, 1660, 4, p. 9)[25] a description which gives a similar picture of the plains surrounding the Dnieper. A modern traveler (p. 85) (*Rich. Chandler travels in Asia minor*)[26] believes that the sea once spread as far as the springs of the Menderes and formed a marine bay between the mountains of Messoghis and Taurus. Others have found former traces of the sea in the plains of Asia minor and Persia, and on the river Danube, very far from the present shores of the Black and Caspian Sea. Old legends about a sudden overflow of the Black Sea through the Sea of Asov, supported by *Tournefort's* observations, appear more plausible in all respects than the opinion that an ancient strait between the Caspian and the Black Sea dried up by silting of the rivers.

TRANSLATORS' NOTES TO THEORY

1. BUFFON, George Louis Leclerc (1749-1804). *Histoire naturelle, générale et particulière, avec la description du Cabinet du Roy...*, Paris, Imprimerie Royale, 44 vols.

2. WOODWARD, John (1695). *An Essay towards a Natural History of the Earth...* London, printed for R. Wilken, 277 p.

3. Pallas means simply high mountains when referring to high Alps.

4. DELIUS, Christoph Traugott (1770). *Abhandlung von dem Ursprunge der Gebürge und der darinne befindlichen Erzadern, oder der sogennanten Gänge und Klüfte; ingleichen von der Vererzung der Metalle und insoderheit des Goldes.* Leipzig, C. G. Hilschern, 156 p.

5. Wendland proposed T. O. Bergmann, P. J. Bergius, C. V. Linné, and J. G. Wallerius in Sweden and J. G. Lehmann, Chr. Füchsel, and A. G. Werner in Germany (Wendland, p. 24-25). Stössner mentioned that three orders of mountains had been distinguished shortly before Pallas by the Swedish mineralogist Johann Jakob Ferber in his *Briefe aus Wälschland* in 1773, published by Ignatz Edler von Born and by von Born himself (Stössner, p. 9). See Chapter I for complete references.

6. PALLAS, P. S. (1771-1776). *Reise durch verschiedene Provinzen...* (reference in Chapter I).

7. The French version published at St. Petersburg (1777, p. 25) says: *Quartz, plus ou moins mêlé de Feldspath, de Mica & de petites Basaltes éparses sans aucun ordre & par fragmens irréguliers, en différentes proportions* (quartz, more or less mixed with feldspar, mica and small basalts, scattered randomly, in irregular fragments, and various proportions) omitting the concept that all these minerals are fused together in granite.

8. The same French version says (p. 25): *Au reste, la matière du granite ne peut avoir été le produit d'un feu de fusion qui en altère plutôt les principes* (Finally, granite cannot be the result of melting fire which rather alters the principles) which is the opposite of Pallas' German version.

9. PAUW, Cornelius (1771). *Recherches philosophiques sur les Américains, ou Mémoires intéressants pour servir à l'histoire de l'Espèce humaine,* 3 vols. Berlin: G. J. Decker.

10. Pallas uses the word "Wacken" for superposed masses of rocks, an old mining term meaning large stones.

11. Pallas changed his mind completely in his later travels published under the title of *Bemerkungen auf einer Reise in die südlichen Statthalterschaften des russischen Reichs in den Jahren 1783 und 1794* (reference in Chapter II). See the English translation, (1812) *Travels through the Southern Provinces of*

the Russian Empire, in the years 1793 and 1794 (reference Chapter II) vol. II, p. 144. In this later work Pallas said: "I shall farther show, in describing other regions of the southern mountains in the Crimea, that many extensive devastations have been occasioned merely by springs undermining the sides and bottoms of steep eminences; and that they are not, as others have supposed, the effects of volcanoes. In the primitive ages of the world, when all the hills were much higher and steeper, and the sea spread its waters to the foot of such eminences, it must have necessarily followed that the floods, as well as the streams or rapid torrents, which flowed in cascades from those elevated precipices, were still more powerful, and occasioned almost incalculable disruptions and sinkings of mountains, before the surface of the globe had acquired its present form." (The first edition of 1802 is identical).

12. Johann Anton Güldenstädt (1745-1781), doctor of medicine and naturalist, member of the Academy of St. Petersburg, who was assigned by the Empress Catherine II to explore the Russian Empire. He worked independently at the same time as Pallas but in a different area, namely Moscow, Volgograd, Astrakhan, and the Caucasus. He wrote *Reisen durch Russland und im Caucasischen Gebürge,* published by Pallas, at the Academy of St. Petersburg, 1787-1791, 2 vols.

13. STRAHLENBERG, P. J. (1730). *Das Nord-und Östliche Theil von Europa und Asia, in so weit solches das gantze Russische Reich mit Sibirien und der grossen Tatarey in sich begreiffet, in einer historisch-geographischen Beschreibung; nebst einer... Tabula polyglotta.* Stockholm. Verlegung des Authoris, 438 p.

—— (no date) *Historie der Reisen in Russland, Sibirien und der grossen Tatarey. Mit einer Landcharte und Kupferstichen, welche die Geographie und Antiquitäten erläutern.* Leipzig, G. Riesewetter [1730?]. 438 p.

14. Pallas used the term of "Flötzgebürge," introduced by the German school, rather than secondary mountains as mentioned in the French version of 1777 (*collines de l'ordre secondaire,* p. 31).

15. BOURGUET, Louis (1729). *Lettres philosophiques sur la formation des sels et des crystaux... avec un mémoire sur la théorie de la terre.* Amsterdam. François L'Honoré, p. 181.

16. On the theory of corresponding angles, see Marguerite Carozzi (1986). From the Concept of Salient and Reentrant Angles by Louis Bourguet to Nicolas Desmarest's Description of Meandering Rivers: *Archives des Sciences, Genève,* 39, 1, p. 25-51.

17. These are the Aleutian Islands described first by the anonymous J. L. S. in *Neue Nachrichten von denen neuentdeckten Inseln in dem See zwischen Asien und Amerika...,* published in Hamburg and Leipzig 1776. For further information see James R. MASTERSON, and Helen BROWER (1948). *Bering's Successors, 1745-1780, Contributions of Peter Simon Pallas to the History of Russian Exploration toward Alaska.* Seattle, University of Washington Press.

18. In other words, the volcanic activity which partially melted, uplifted, and mineralized the shales, turning them into metamorphic schists, also involved the margin of granite on which the shales were resting and generated a large-scale transition zone between granite and schists.

19. Pallas seems to have observed a certain specific superposition of lithologies within the schistose band on the eastern side which is as follows from the granite contact: unspecified transitional rocks to granite; calcareous schists (mineralized in copper) interbedded with jasper (radiolarites); hornschists and serpentine-schists (diabases and ophiolites). This sequence, today indicative of a subduction zone, is in fact repeated several times in the schistose sequence of the main trough of the Urals (See Chapter IV).

20. In the French version (p. 46, 1777), this sentence was abbreviated into: *Nous pourrons parler plus décisivement sur les montagnes secondaires & tertiaires de l'Empire* (we are better informed about secondary and tertiary mountains in the Empire). Pallas used the expression of first, second, or third order instead of primary, secondary, and tertiary mountains.

21. He noticed that the planes of schistosity of schists were parallel to the bedding planes of limestones *(Richtung der Ablösung in den Schiefern).*

22. The orientation of limestones at right angle to the Urals occurs only at one place on Pallas' map near Lake Tschernoi. It corresponds to a large mass of Lower Devonian marbles and limestones trending N-E compared to the N-S surrounding schists.

23. Pallas seemed to have two explanations concerning the origin of volcanic fires, in general agreement with those of his time. In the case of the vertical primitive schists, the infiltration of iron and marine organic matters generated pockets of pyrite that took fire. In the case of the thick clay layer underlying the secondary limestones, an association of pyrite and marine organic matter contributing to the formation of coal-like shales (bituminous shales) combined as fuel. At the time, no distinction was made between black carbonaceous and black bituminous shales, but Pallas certainly meant the latter when using the term of *brennliche Schieferarten* or inflammable shales.

24. The French version introduces the tzars as "PIERRE LE GRAND & L'AUGUSTE CATHERINE SECONDE", (p. 52, 1777) to honor the tzars.

25. Pallas said here that the band of schists as well as the band of limestones, next to the granitic rocks, have their counterparts in the plains [when exposed by river cuts] except that fire has melted and burned rocks adjacent to granite and left untouched those in the plains, including fossils. This corresponds to the modern understanding that contact-metamorphism changes shales into schists and limestones into marbles. However, Pallas thought merely about contact with the fires of volcanoes and not heat, pressure, and chemical solutions. The French version (p. 56-57, 1777) has omitted the latter part of this important view, saying that *par la violence active des feux, les matières de ces couches, produisirent les premières montagnes de la bande schisteuse qui répond en partie aux lits d'argille & de sable des plaines; ainsi que ces montagnes calcaires dont la roche est solide & pour la plûpart sans traces de pétrifications* (by the active violence of [volcanic] fires the materials of these layers [were changed and] produced the first mountains of the band of schists — which corresponds in part to the beds of clay and sand in the plains — as well as the limestone mountains whose rocks are solid and mostly without any petrifications).

26. The French version mentions instead (p. 58, 1777)... *des convulsions du globe qui purent, par des éruptions gigantesques au plus profond des mers, soulever et chasser les flots jusqu'à inonder violemment une grande partie des terres déjà habitées, des montagnes même assés élevées, & augmenter les continens.* (...floods covered large parts of inhabited lands, as well as rather high mountains), whereas Pallas said that some mountains were *formed* at that time.

27. FONTENELLE, Bernard le Bouvier de (1716). *Sur l'origine des pierres* (On the origin of rocks): *Histoire de l'Académie Royale des Sciences,* Paris, p. 9-18. Based on two memoirs by Étienne François Geoffroy (1672-1731) and de la Hire, fils, Fontenelle wrote: "It is proven that all rocks consisted in the past of a soft mud. Since there are quarries almost everywhere, the surface of the Earth must have consisted of mud in all these places, at least down to a certain depth. Fossils found in most quarries prove that this mud is an earth that was once diluted by the waters of the sea, and hence the ocean has covered all these areas... Thus were formed all the beds or layers of rocks which occur horizontal and parallel to each other in the plains. Fish must have been the oldest animals on Earth; terrestrial animals and birds did not exist as yet. But how did the ocean retreat into the great caverns, the vast basins which it occupies presently? What comes first to our mind is the idea that the Earth [crust] was not solid everywhere, at least down to a certain depth, but included some great caverns, the arches of which kept up during a certain time. However, when these arches suddenly gave way, the waters fell into these caverns, filled them, and exposed part of the surface of the Earth which became a convenient home for terrestrial animals and birds... It is very plausible that other parts of the surface of the Earth were lifted by the same cause."

28. Pallas' footnote on the floods of the Neva at St. Petersburg is missing in the French text.

29. In an earlier footnote (14), Pallas was opposed to the proposition that fossils found in European limestone layers originated from the Indian Ocean whereas he seemed to agree now with Antoine Jussieu that imprints of ferns and other plants found in European shales were transported from the south or from the Indian Ocean. Jussieu's memoir is entitled, *Examen des causes des Impressions des Plantes marquées sur certaines Pierres des environs de Saint-Chaumont dans le Lionnois* (Analysis of the causes of plant imprints in certain rocks near Saint-Chaumont in the Lyonnais): *Académie Royale des Sciences,* Paris, 1718, p. 363-376. In the Lyonnais coal beds, Jussieu had found some imprints of capillary plants and ferns that were similar to those found by Father Plumier and Sloane on the islands of America and those sent from the East and West Indies to England. Based on the evidence that the plants were mostly in a flat position, he deduced that they must have floated in water; since they were surrounded by marine shells, the environment must have been the sea; and because similar plants existed in India, or in other warm countries, an ocean from India or thereabouts must have brought them to France.

30. The French version mentions merely the ocean's irruption but not its retreat (p. 61, 1777).

31. The French version says instead of "the reader", *cette illustre Assemblée* (this illustrious assembly, p. 63, 1777) which proves that the French text was read at the Assembly of the Academy of St. Petersburg by Pallas who spoke French. Nevertheless, some embellishment and slight to serious misrepresentations of geological details might have been made by the person who translated Pallas' original essay from the German into French. When publishing this essay in German, his own ideas are expressed more clearly.

TRANSLATORS' NOTES TO PALLAS' FOOTNOTES

1. CHAPPE D'AUTEROCHE, Jean, Abbé (1762). Mémoire du passage de Venus par le Soleil; contenant aussi quelques autres observations sur l'astronomie et la déclinaison de la boussole, faites à Tobolsk en

Sibérie l'année 1761: *Imperial Academy of St. Petersburg.* 22 p.; and (1768) *Voyage en Sibérie fait par ordre du roi en 1761, contenant les mœurs, les usages des russes, et l'état actuel de cette puissance, la description géographique et le nivellement de la route de Paris à Tobolsk, l'histoire naturelle de la même route.* Paris. Debure père, 2 vols. in 3.

IDES, Evert Ysbrandzoon (1707). *Dreyjährige Reise nach China, von Moscau ab zu Lande... gethan durch den Moscovitischen Abgesandten Herrn E. Y. T. 1707, Alles aus dem Holländischen übersetzt.* German translation of the Dutch first edition of 1704. Frankfurt, T. Fritsch. 1707. 466 p.

LANGE, Lorenz (1781). Tagebuch zwoer Reisen, welche in den Jahren 1727, 1728 und 1736 von Kjachta und Zuruchaitu durch die Mongoley nach Peking gethan worden von Lorenz Lange, ehemaligen Russ. Kays. Kanzleyrath. Nebst einer geographisch-historischen Beschreibung der Stadt Peking. Aus ungedruckten Quellen mitgetheilt von Herrn Prof. Pallas: *Neue Nordische Beyträge.* Leipzig. 152 p. (See Wendland, 1986, p. 57, reference in Chapter I).

2. See note 13 in Translators' Notes to Theory.

3. PAUW, Cornelius de (1768-1769), *Recherches philosophiques sur les Américains, ou Mémoires intéressants pour servir à l'histoire de l'Espèce humaine.* 3 vols. Berlin. G. J. Decker.

4. NIEBUHR, Carsten (1774-1837). *Reisebeschreibung nach Arabien und andern umliegenden Ländern.* 3 vols. Kopenhagen, N. Möller.

5. Jean Chardin, traveler of the Orient.

6. PENNANT, Thomas (1771). *Synopsis of Quadrupeds.* Chester, J. Monk, 382 p.

7. ZIMMERMANN, E. A. W. von (1777). *Specimen zoologicae geographicae, quadrupedum domicilia et migrationes sistens...* Lugduni Batavorum. Theodor Haak et socios, 4°, 685 p.

8. LINNÉ, Carl von (1735). *Systema naturae, sive Regna tria naturae systematice proposita per classes, ordines, genera, et species.* Lugduni Batavorum, J. W. de Groot, 12 p. folio.

9. FRISI, Paolo (1751). *Disquisito mathematica in causam physicam figurae et magnitudinis telluris nostrae.* Mediolani, Regia curia, 87 p.

—— (1768). *De gravitate universali, corporum libri tres.* Mediolani, J. Galeatium, 420 p.

—— (1756). *Dissertatio de motu diurno Terrae.* Berlin, Haude and Spener, 83 p.

10. PALLAS (1771-1776). *Reise durch verschiedene Provinzen...,* Part III, p. 535.

11. The French version says that *c'est des masses granitiques ainsi détachées qui ont paru merveilleuses à Bourguet* [footnote p. 41, 1777].

12. WALLERIUS, Johan Gottsckalk (1750). *Mineralogie oder Mineralreich...* Translated by J. D. Denso, Berlin, C. G. Nicolai, 600 p. and (1763) same title, translator, and publisher, 600 p.

13. PALLAS, *Reise durch verschiedene Provinzen...* Part III, p. 411-417. This so-called iron ore was later on recognized as being a meteorite by E. E. F. Chladni. Its modern name is pallasite. For further details, see CAROZZI, A. V. (1990). Histoire des sciences de la terre entre 1790 et 1815 vue à travers les documents inédits de la Société de physique et d'histoire naturelle de Genève,... *Mémoires de la Société de physique et d'histoire naturelle de Genève.* 45, 2, p. 170-171.

14. BUACHE, Philippe (1742). Essai de géographie physique où l'on propose des vûes générales sur l'espèce de charpente du globe, composée de chaînes de montagnes qui traversent les mers comme les terres... *Mémoires de l'Académie Royale des Sciences,* Paris, p. 399-416.

15. The French version omits the infiltration of water (footnote p. 47, 1777).

16. PALLAS (1773). De reliquiis animalium exoticorum per Asiam borealem repertis complementum: *Imperial Academy of Sciences, St. Petersburg.* New Commentaries, Vol. XVII (1772), Summary p. 39-41, Memoir p. 576-606, see p. 595.

17. This footnote is missing in the French version.

18. Johann Georg Leutmann (1667-1736) Professor of mechanics and optics at the Academy of Sciences of St. Petersburg.

19. WEBER, Friedrich Christian (1721). *Das veränderte Russland, in welchem die jetzige Verfassung des Geist- und Weltlichen Regiments; der Krieges-Staat zu Lande und zu Wasser:... die Begebenheiten des Czarewitzen... vorgestellet werden,* 4 vols. in 1. Frankfurt, N. Förster, 1726-1740.

20. Johann Jakob Lerche (1709-1780), Professor of medicine at the University of Leipzig.

21. Stepan Petrovic Kraseninikov (1713-1755), took part in the Northern Expedition and wrote (1755) *Description of the Land of Kamchatka,* St. Petersburg, Academy of Sciences (in Russian).

22. STELLER, Georg Wilhelm (1774). *Beschreibung von dem Lande Kamtschatka, dessen Einwohnern,*

deren Sitten, Nahmen, Lebensart und verschiedenen Gewohnheiten, published by J. B. S. [Johann Benedikt Scherer], Frankfurt and Leipzig, J. G. Fleischer, 348 p.

—— (1793)... *Reise von Kamtschatka nach Amerika mit dem Commandeur-Capitän Bering. Ein Pendant zu dessen Beschreibung von Kamtschatka,* published by P. S. Pallas, St. Petersburg, J. Z. Logan, 132 p.

23. This footnote is important for Pallas' notion of a flood transporting skeletons to Siberia and elsewhere in Russia.

24. Joseph Pitton de Tournefort (1656-1708), Professor of botany at the Jardin des Plantes in Paris. According to Wendland (1986, p. 72), it was not Tournefort but Buffon who actually mentioned an earlier communication between the Black and the Caspian Sea.

25. BEAUPLAN, Guillaume Le Vasseur, Sieur de (1660). *Description d'Ukrainie, qui sont plusieurs provinces du Royaume de Pologne; contenues depuis les confins de la Moscovie jusques aux limites de la Transsilvanie; ensemble leurs mœurs, façons de vivres, & de faire la guerre.* Rouen, Jacques Cailloüe, 112 p.

26. CHANDLER, Richard (1775). *Travels in Asia Minor, or, an Account of a tour made at the expense of the Society of Dilettanti.* Oxford, Clarendon Press, 283 p.