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PALLAS' THEORY OF THE EARTH IN GERMAN (1778) TRANSLATION AND REEVALUATION REACTION BY A CONTEMPORARY: H.-B. DE SAUSSURE

BY

ALBERT V. CAROZZI
AND MARGUERITE CAROZZI

P. S. Pallas,

Mitglied der Akademien zu St. Petersburg und Stockholm, wie auch der Londner, der Berlinischen naturforschenden und der Rußischen ökonomischen Societät,

Betrachtungen

über die

Beschaffenheit der Gebürge

und

Veränderungen der Erdkugel,

besonders in Beziehung auf das Rußische Reich.

Vorgelesen

in der öffentlichen Versammlung der Rußisch-Kaiserl. Akademie der Wissenschaften

den 23ten Junius 1777,

da dieselbe

mit der hohen Gegenwart

des Herrn Grafen von Gothland

beehret wurde.

Frankfurt und Leipzig 1778.

Frontispiece: Title page of Pallas' Theory of the Earth (1778).

PALLAS' THEORY OF THE EARTH IN GERMAN (1778) TRANSLATION AND REEVALUATION REACTION BY A CONTEMPORARY: H.-B. DE SAUSSURE

Albert V. CAROZZI and Marguerite CAROZZI *

RÉSUMÉ

Cet article donne un nouvel aperçu de la contribution à la géologie de Pierre Simon Pallas. Une traduction complète en anglais est donnée de la version allemande de sa théorie de la terre (1788) qui est plus représentative des idées de Pallas que la version française, souvent inexacte. La réaction immédiate de son contemporain H.-B. de Saussure est présentée ici pour la première fois; elle est d'un grand intérêt car elle contient non seulement de nombreuses citations extraites des voyages et de la théorie de la terre de Pallas, mais aussi des critiques perspicaces et des commentaires très appropriés. En effet, Saussure semble avoir prêté à Pallas beaucoup plus d'attention qu'à aucun autre naturaliste contemporain. Bien qu'il ait maintenu son opinion sur l'origine aqueuse du granit, entièrement opposée à celle ignée de Pallas, Saussure a cependant accepté, de manière tout à fait honnête, certaines vues globales de Pallas. Dans l'épilogue (Chapitre IX) est mentionné qu'après la parution du premier volume de *Voyages* (1779) de Saussure, Pallas, de son côté, a accepté en 1781 l'origine du granit par cristallisation dans un liquide.

Une revue critique des nombreuses citations ultérieures de l'œuvre de Pallas, de 1897 à 1986, montre qu'à l'exception de deux historiens allemands, Arthur Stössner et Folkwart Wendland, un seul argument de la théorie de Pallas n'est en général mentionné, à savoir, que toutes les grandes chaînes de montagnes sont formées par une zone centrale de granit, bordée des deux côtés par trois bandes principales: roches schisteuses primitives, calcaires secondaires, et grès et schistes tertiaires. Cependant, les descriptions précises par Pallas des roches de la chaîne de l'Oural sur lesquelles sa théorie a été basée, n'ont jamais été mentionnées, et de plus n'ont jamais fait l'object d'une comparaison avec nos connaissances modernes de la géologie de cette chaîne.

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Pour interpréter les observations de Pallas faites entre 1768 et 1774, ainsi que sa carte géologique de l'Oural de 1773, nous avons utilisé une procédure nouvelle qui consiste en une transcription graphique de sa carte basée sur des symboles ponctuels des principales lithologies en bandes équivalentes suivant l'usage des cartes modernes. La grande ressemblance de la carte de Pallas à la carte géologique moderne de la chaîne de l'Oural est frappante, y compris la courbure de la chaîne contre le plateau de l'Ufa. En effet, il n'a pas trouvé de granit dans la zone axiale, mais des quartzites feldspathiques (correspondant au Précambrien métamorphique qui est effectivement formé de micaschistes et de quartzites feldspathiques). De plus, les bandes schisteuses primitives ne sont pas symétriques des deux côtés de la zone axiale: Pallas a trouvé sur le versant ouest des grès et des schistes non métamorphiques, et sur le versant est des schistes très métamorphiques et minéralisés accompagnés de jaspes, de marbres et de serpentines. Il a aussi observé que les calcaires secondaires sont bien développés à l'ouest, mais difficilement reconnaissables à l'est. Seuls les grès et les schistes tertiaires apparaissent uniformément développés des deux côtés. En résumé, comme indiqué sur les cartes géologiques modernes, la structure de l'Oural selon Pallas est asymétrique et la zone axiale n'est pas constituée de granit.

La contribution de Pallas à la géologie de l'Oural par la quantité et la précision des observations est unique pour son époque, tandis que sa théorie sur les montagnes en général, a été écrite, comme il le dit lui-même, pour être en accord avec les idées des grands naturalistes allemands et suédois. Ne disposant même pas de deux semaines pour la préparation de sa théorie pour une présentation orale à l'Académie des sciences à St. Pétersbourg, devant un invité d'honneur, le Roi de Suède, il a trouvé plus convenable de critiquer seulement Buffon et de montrer son accord avec les naturalistes suédois. En d'autres mots, il a sacrifié ses propres et précises observations pour des raisons politiques, c'est-à-dire pour faire plaisir à l'Impératrice de Russie qui avait supporté ses recherches. De cette façon, sa gloire s'est perdue rapidement quand les observations sur le terrain sont devenues le critère principal de la recherche géologique.

ABSTRACT

This paper presents a new insight into Peter Simon Pallas' contribution to geology. A translation is given of the German version of his theory of the Earth (1778) because it is more representative of Pallas' thinking than the sometimes inaccurate French version (1777). The immediate reaction of his contemporary, H.-B. de Saussure, made public here for the first time, is of greatest interest because of his numerous excerpts of both Pallas' travels and the theory of the Earth, with, in particular, his sharp criticism and appropriate comments on many of Pallas' views. In fact, Saussure paid much more attention to Pallas than to any of his other

contemporaries. Though he maintained his opinion about the origin of granite, which was the opposite of that of Pallas, he candidly agreed with some of Pallas' global views. In the epilogue (Chapter IX) the reader will find that after the publication of the first volume of Saussure's *Travels* (1779), Pallas accepted in 1781 the origin of granite by crystallization in a liquid.

A critical review of the numerous subsequent accounts of Pallas between 1897 and 1986 shows that, with the exception of two German historians, Arthur Stössner and Folkwart Wendland, only one argument of Pallas' theory of the Earth is generally cited, namely, that all major mountain ranges consist of a central zone of granite, followed on both sides by three major bands: primitive schistose rocks, secondary limestones, and tertiary shales and sandstones. However, Pallas' precisely described rocks of the Urals, on which his theory was based, have never been reported, nor have they been compared to those shown on modern maps of that region.

To interpret Pallas' observations made between 1768 and 1774 and his geological map of the Urals (1773) we have used a new procedure, namely a graphic transcription of his map based on punctual symbols of the major rock-types into equivalent bands as in modern maps. The result is striking: Pallas' map resembles very much the modern geologic map of the Urals, including the bending of the chain against the Ufa plateau. He did, in fact, not find granite in the axial zone but feldspathic quartzites (corresponding to Precambrian metamorphic rocks which consist of micaschists and feldspathic quartzites). Furthermore, the primitive schistose bands are not symmetrical on both sides of the axial zone: Pallas found non-metamorphic shales and sandstones on the western slope, and highly metamorphic and mineralized schists, accompanied by jaspers, marbles, and serpentines, on the eastern slope. He also noticed that secondary limestones are well developed on the west but hardly recognizable on the east side. Only the tertiary shales and sandstones appeared equally developed on both sides. In short, as on modern geological maps, Pallas' structure of the Urals is asymmetrical and the axial zone consists of rocks other than granite.

Pallas' contribution to the geology of the Urals is unique at his time because of its wealth of precise observations whereas his theory on mountains in general was written, as he said himself, to agree with the ideas of the great German and Swedish naturalists. Since he had less than fourteen days to prepare his theory for oral presentation at the Academy of St. Petersburg in front of a guest of honor, the King of Sweden, he thought it probably more appropriate to criticize only Buffon and to agree with Swedish naturalists. In other words, he sacrificed his personal accurate observations for political reasons to please his benefactor, the Empress of Russia, and thus his fame was soon lost when field observations became the major criteria in geological investigations.

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INTRODUCTION

Peter Simon Pallas belongs to that brand of naturalists who advanced geological knowledge in the eighteenth century by precise descriptions of various kinds of rocks visible at the surface of the Earth. He traveled extensively between 1768 and 1774 through a large part of Russia but drew a geological map of the Ural Mountains only, giving symbols for rocks as well as for minerals in mining districts. In 1777 he was asked to give a talk at the Academy of Sciences at St. Petersburg in which he included his observations and a theory of the Earth. Today, his fame rests not on his precise geological observations but on the statement given in his theory of a central chain of primitive mountains (granite and schists) in the Urals, accompanied on both sides by limestone mountains, and finally by layers of marls, sandstones, and clays.

Pallas' contemporary, H.-B. de Saussure's, carefully analysed both Pallas' theory as well as his geological observations, being well aware that those observations served as basis for his theory (see Chapter IV). However, today, Pallas' geological observations are forgotten and his once famous theory "On the nature of mountains and on changes that have occurred on the globe" (first published in French by the Academy of Sciences of St. Petersburg in 1777) is generally cited by historians in a few lines. Only Arthur Stössner presented in his doctoral thesis (1900) a thorough investigation of all of Pallas' geological investigations rather than describing merely Pallas' theory of the Earth. However an analysis of Pallas' geology of the Urals is missing (see Chapter V). Folkwart Wendland (1986) gave a detailed account of Pallas' German theory published in 1778 to which he added a biography and some comments on Pallas' geological interpretations (Chapter V). Nevertheless, though Wendland noticed that Pallas made a distinction between the eastern and western side of the Urals, he treated Pallas' geological knowledge of these mountains according to their classification into mountains of first, second, and third order, giving neither a hint about the locations where Pallas found these various rocks nor how they fit into the modern interpretation of the Ural Mountains.

This paper includes first a translation of Pallas' German theory of 1778 which has not been published in English. It remains a marvelous and very readable piece of eighteenth-century scholarship. Pallas gave not only a description of the nature of mountains and possible reasons for the great changes that have occurred on Earth, but he also talked about the origin of the black race; the first settlements of humans; their first civilization; the various climates of Siberia; the animals and plants native to Central Asia; the belief that the natives of Tibet were the descendants of apes;

and the many recorded floods of the Neva at St. Petersburg. These ideas, often unrelated to geology, are mostly in footnotes some of which were omitted in the French edition of 1777.

Pallas wrote a German edition a year later perhaps because the felt that the French paper was not entirely representative of his own ideas. Read in French at the Academy of St. Petersburg for a guest of distinction (the King of Sweden), Pallas' talk was actually meant to show the European scientific public what the Academy of Sciences at St. Petersburg was capable of doing. Those who have read the St. Petersburg version, or any later French version, are missing the original thoughts of Pallas because many views in the French edition differ from the German and are at times even contradictory. We believe therefore, that a faithful translation of Pallas' German essay of 1778, including all his footnotes, would please those readers who are not conversant in that language, and perhaps also those who have never read Pallas at all.

Second, we are giving here an explanation of Pallas' description of geological features as he recorded them during his 1768-1774 expedition and drew them on his map. On the basis of a reconstruction of this map, these observations are compared with the modern geology of the Urals as well as with his theory of 1778. With this reevaluation of Pallas' contribution, we are hoping to fill one more gap in the history of geology of the eighteenth century.

With respect to footnotes and pagination, either by Pallas or the translators, the following standards were adopted: Pallas' footnotes are given at the end of his theory (Chapter III). Pallas' original pagination and footnote numbers are given in parentheses both in the theory and in Pallas' footnotes (plain text). Our footnotes and references are marked by superscript numbers (bold) in the translation. They include bibliographical references, explanations about some of Pallas' terms, and clarifications of Pallas' geological observations; they point also to discrepancies between the French and the German text. Minor complementary information by the authors is in square brackets. References follow all chapters with the exception of III and VIII; Pallas' publications follow a short biography in chapter I. The spelling of Russian rivers and cities has been modernized with the exception of names not found on any modern map.

ACKNOWLEDGMENTS

We are very grateful to Martin Guntau for sending us the latest review of Pallas by Folkwart Wendland and the doctoral thesis of Arthur Stössner which was very difficult to find. We also wish to thank J. K. Newman for his help in the interpretation of Latin terms. Jessie Knox is thanked for his fine drafting of the figures.

CHAPTER I

BIOGRAPHY OF PALLAS

Peter Simon Pallas (1747-1811) was first a student of medicine at Halle, Göttingen, and Leiden but soon became interested in a variety of other fields in the natural sciences. Searching in vain for a position in Germany and Holland, he accepted the invitation of the Empress Catherine II to work at the Academy of Sciences at St. Petersburg. He spent the next forty years in Russia and participated in the "Academic expedition" of 1768-1774. His results were published (Pallas, 1771-1776) in German and then translated into Russian, French, English, and Italian. The theory of the Earth discussed in this paper was written for a talk at the Academy of Sciences at St. Petersburg (Pallas, 1777; the German version of 1778 is translated here). He wrote a great number of articles in Latin on zoology, botany, and other subjects of natural history which were published in various German cities and at St. Petersburg (see list of works of Pallas given by K. A. Rudolphi in a reprint [1967] of Pallas 1771-1776 travels). He was furthermore editor of 7 volumes of *Neue Nordische Beyträge...* (1781-1793), including articles written by him and other naturalists. Twenty years after his first expedition, Pallas undertook a second but shorter trip to the Caspian Sea (1799-1801). When he finally decided to return to his home town Berlin in 1810, he died one year later. For further information see F. Wendland (1986), the Introduction by Dietmar Henze to a reprint of the first expedition of Pallas (1967), and Vasily A. Esakov's article in the DSB.

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CHAPTER II

EIGHTEENTH-CENTURY TERMINOLOGY OF SCHIEFER AND GRANITE

Schiefer

The German term of *Schiefer* raises a critical problem of terminology for translation. It does not discriminate between *shales,* that is, argillaceous sedimentary rocks characterized by thin laminae representing bedding planes, and *schists,* their slightly- to highly metamorphic equivalents. When shales change into schists by the addition of new minerals, they display a new striking planar structure called *schistosity*. These planes generally develop obliquely, at a variable angle to the laminae of the original shales. Transformation of shales into schists may result from moderate tectonic stresses and shallow burial accompanied by slight mineralogical changes (to produce slates, for instance) or from strong tectonism associated with deep burial under high pressures and temperatures and related important mineralogical changes (micaschists, garnet-schists).

Pallas named rocks in the schistose bands which are immediately adjacent on both sides to the axial granites: primitive *Schiefer*. However, he emphasized that those of the eastern band were more metamorphic and more mineralized than those of the western band which he also called *Schiefer*. In reality (see Chapter VI), the western schistose band consists mainly of highly folded Ordovician to Devonian shales, bituminous shales, and sandstones whereas only Cambrian metamorphic schists (phyllites) are weakly metamorphic and lie against vertical Precambrian metamorphics. The eastern schistose band however consists of highly metamorphic schists with intercalated ophiolites and jaspers.

Furthermore, in his description of mountains of third order, Pallas used again the word Schiefer in *Sandschiefer* for shales and arenaceous shales of younger geological age.

In this translation, the terms *shales,* for sedimentary, and *schists,* for metamorphic rocks, have been used according to the modern geological context of the Urals to avoid the confusion generated by translating indiscriminately *Schiefer* by schists.

Granite

Pallas' manner of describing rocks called *granite* reveals problems of terminology during the eighteenth century. He knew, and said so in his theory, that the most common composition of granites which form the top or the core of great mountain chains was quartz, feldspar, and mica. Granites occur, he specified, mostly in large masses. Nevertheless, he observed in the Ural Mountains that the rocks typical of the axial chain consisted of highly inclined beds of feldspar and quartz. He did not use the word granite and in his map of the Urals he described these rocks correctly as *Vitrescirendes Gebürge u. Quarz* (vitreous rocks and quartz). Sometimes in 1776, he changed his mind because he must have read J. G. Wallerius *Systema Mineralogicum...* (1772), the most famous book on mineralogy at that time.

According to Wallerius (1772), granites included various types of rocks:

"SAXA DURA, GRANULARIA, SOLIDA, AD CHALYBEM SCINTILLANTIA, QUAE NON FISSILIA ET VIX IN STRATIS REPERIUNTUR. GRANITAE."

Spec. 199: " 1. SAXUM Quartzo & spato scintillante, in diversa proportione, mixtum. GRANITES SIMPLEX" [namely quartz and shiny feldspar in various proportions; today either a feldspathic quartzite or an aplite or a pegmatite].

Spec. 200: "2. SAXUM, Quartzo & Basaltico lapide, in diversa proportione mixtum, GRANITES BASALTICUS" [the modern aplite or pegmatite with tourmaline].

Spec. 201: "3. SAXUM, Quartzo, Spato scintillante & Mica, in diversa proportione mixtis, compositum. GRANITES..."

"Est compositum Saxum à *Quartzo, Spato scintillante & Mica,* fortius vel debilius, in diversa proportione, coadunatis; à diversitate lapidum componentium diverso gaudens colore; durum, ad chalybem scintillans, polituram suscipiens plus minus perfectam, pro diversitate combinationis particularum; reperitur etenim vel *granulare* vel quasi in *unam massam fusum*; in igne fragile & pulverulentum redditur. Multiplici est differentia, lieat, principaliores solum describere varietates." [This is the modern description of the composition of granite, that is, quartz, feldspar, and mica, in various proportions, with either a granular or a smooth texture. Wallerius' expression *quasi in unam massam fusum,* however, does not mean "fused together in a fire," but simply mixed into a mass with a smooth surface. In Latin, the word *ignis* or *calor* would have to be added to refer to the origin of granite by fire.]

H.-B. de Saussure (1779) followed Wallerius (1772) but considered Species 199 rather rare in the Alps, Species 200 very common, and Species 201 actual granite [*granit proprement dit*], that is, that type of granite which is characteristically forming the highest peaks of the Alps.

In the eighteenth century, the term granite was thus not given only to Species 201, most typical for granites, but also to rocks consisting only of two major components (quartz and feldspar) and a variety of other combinations of minerals forming rocks called today granodiorites and diorites. Henceforth, Pallas might have changed the term *Vitrescirendes Gebürge u. Quartz* for rocks forming the axial chain of the Urals to *Granite* because other famous contemporary German and Swedish naturalists said that the axial chain of high mountains consisted of granite.

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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 produced 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 Kupfterstichen, 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.

CHAPTER IV

A CONTEMPORARY CRITIC OF PALLAS' THEORY: H.-B. DE SAUSSURE

INTRODUCTION

During his entire life, Saussure had planned to write a theory of the Earth that circumstances and poor health prevented him from developing beyond two versions of a detailed table of contents. On the basis of his carefully-dated field notes and short memos, it has been possible to reconstruct, year by year, the precise chronological evolution of his thinking and to present what his unpublished theory, based mainly on the Alps, might have been (Carozzi, 1989).

Whenever time was available between his geological trips [published in four volumes under the title of *Voyages dans les Alpes...* 1779-1796], Saussure read numerous books and articles which he selected as critical for his future theory of the Earth. His excerpts on these works are as meticulously kept as his field notes and included in booklets called *Extraits raisonnés* [Critical Excerpts] which he prefaced as "Subjects of my reflections and investigations."

Among his numerous excerpts, the most extensive, and also fully annotated, are those pertaining to Pallas' three volumes of *Travels* in German [1771-1776] as well as his *Theory of the Earth* in French [1777]. He wrote both excerpts at the end of 1778 (Saussure, 1778). They show the great importance that Saussure attributed to Pallas' challenging theory of the Earth that had just appeared, a theory based on geological assumptions conflicting with his own.

Saussure's detailed analysis of Pallas' observations and theory was carried to the extent of preparing a glossary of German terms on structural geology and mining which is still of great interest today and is reproduced below.

Before completing his critical reading of Pallas' *Theory of the Earth,* on November 17, 1778, Saussure was prompted to reexamine some of the fundamental concepts of his own theory of the Earth in the light of what he had just read. His synthetical comments were written between November 14 and December 7, 1778, in a booklet entitled "*Idées détachées qui doivent servir à mon ouvrage sur les montagnes*" (Loose thoughts to be used in my forthcoming book on mountains, i.e. theory of the Earth). From these comments we shall present only those portions dealing with Pallas.

These three unpublished documents representing Saussure's thorough analysis of Pallas' ideas provide not only the rare and unusual opportunity to record the candid opinion of a famous contemporary naturalist but also a better understanding of Saussure's own ideas, revealed through his reaction to Pallas' concepts.

Since this critical analysis of Saussure was undertaken at the end of 1778, it is necessary to describe briefly the status of the evolution of his ideas at that time (Carozzi, 1987, 1989). Saussure assumed the existence of a universal ocean, initially deep enough to cover the highest mountains but decreasing in volume and in temperature with geological time. Granite was deposited as the first chemical precipitate in thick horizontal layers, overlain by gneisses, both forming the *Primitive Rocks. Transition Rocks,* that is, marbles, schists, and hornstones were then deposited by a combination of chemical and mechanical processes. These were overlain in turn by *Secondary Rocks* consisting of thick fossiliferous limestones with a marine fauna that became more abundant and more diversified with time. *Tertiary Rocks,* mainly marine and freshwater sandstones and shales, were then deposited. Finally, often unconsolidated breccias and conglomerates, dating from the great flood or *grande débâcle,* completed the sequence (Fig. 1).

Saussure visualized at least three successive orogenic events, comparable to violent earthquake shocks. Each event was followed immediately by its own flood or *débâcle* during which oceanic waters partially disappeared into large caves within the Earth's crust. These orogenic events and their related floods increased with time in intensity. The various floods are attested by layers of conglomerates and breccias which represent products of destruction of temporarily uplifted areas (Fig. 1). The first flood occurred between Primitive and Transition Rocks (Vallorcine Conglomerate); minor ones are represented by intraformational shelly breccias within Secondary Rocks. The second flood occurred between Secondary and Tertiary Rocks (Mornex Conglomerate). The third flood took place over the Tertiary Rocks and followed the final and major uplift of the Alps. Saussure believed that deposits seen today correspond to the last major flood (in fact Pleistocene glacial and interglacial deposits with their huge erratic blocks).

With respect to orogenic mechanisms, Saussure believed in 1778 in a succession of earthquake-generating explosions of elastic fluids enclosed in caves within the Earth's crust. These explosions increased in intensity with time but were completely unrelated with heat or volcanism. Apparently, only the last and most powerful explosion led to a permanent topographic expression and to the final formation of the Alps as seen today. It is only in 1784 that Saussure reached the critical concept of *refoulements* (horizontal compression) by yet unknown subterranean forces, perhaps related to an early vision of contraction of the globe (Carozzi, 1989).

Saussure's excerpts of Pallas' travels

These excerpts are given here as short summaries by Saussure of Pallas' German text, including Pallas' pagination, followed by Saussure's comments in italics with pagination of his booklets. Saussure's critical remarks on the three volumes of *Travels...* are not so numerous as those on the *Theory of the Earth,* apparently

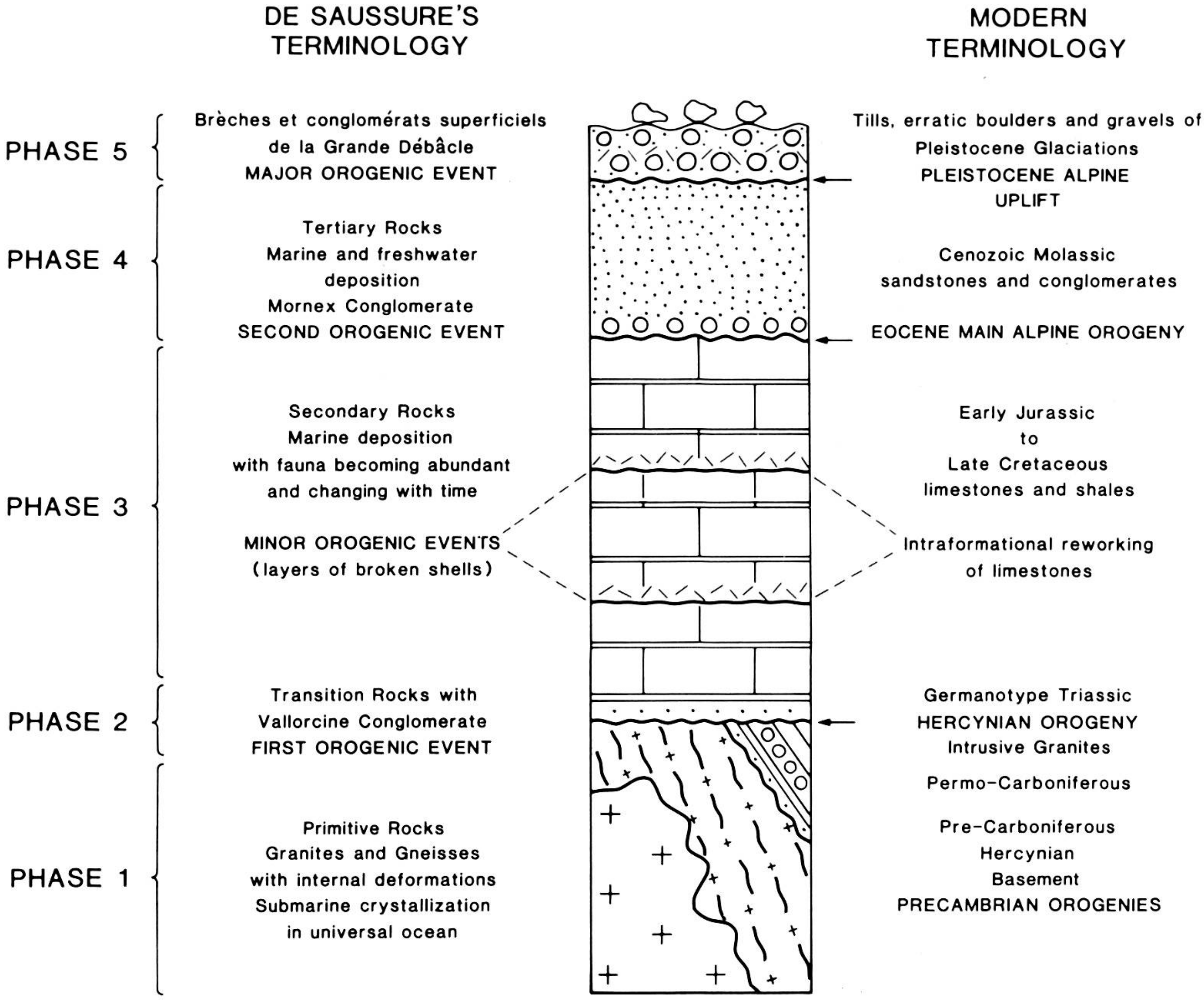

FIG. 1.

Comparison between Saussure's terminology and the modern terminology of major stratigraphic subdivisions and orogenic phases of the Alps from Carozzi (1989).

because he wanted first to analyze carefully Pallas' observations and wait for the final synthesis to express his opinion in full. Explanations by the authors of this paper are given between square brackets.

Volume 2. According to the author, the highest chain of the Urals consists as in other major mountains of granite [Pallas mentioned this in his foreword to Part III of his *Reise* (1771-1776) but not in his theory of 1778].

At first I had some doubts about what M. Pallas called feldspar when he said (p. 65) that rocks of the high and extended mountain of Dsilia-Tau, the northern part of which is still covered with much snow, consist of what is called feldspar *variegated with whitish, gray, and reddish colors* [Pallas did not mention Dsilia-Tau on his map].

But I became convinced that it was a granite in which feldspar predominates when I read, on page 72, that the mountain chain, to which the Bashkirs give properly and exclusively the name of Ural Mountain or Ural-Tau, whose flanks and salients are famous for the abundance of their mines, has as matrix a gray, reddish, or, white feldspar, or quartzose rocks which appear everywhere in standing beds which dip eastward with different degrees of inclination, reaching up to 60° (p. 54). [The composition of rocks in the highest chain of the Urals is in fact a major enigma in Pallas' field observations. Whereas his theory said that granite is forming the highest peaks of major mountain chains, he did not use the term granite for rocks forming the watershed of the Urals. Saussure too seemed at first baffled by the absence of the word granite in the Urals. In the Dsilia-Tau, Pallas mentioned rocks consisting of feldspar only and in those of the Ural-Tau, he found feldspar predominating over quartz. The main reason for Pallas' attitude was that the axial zone of the Ural-Tau does not show granite as he understood the term. (In reality, it consists of Precambrian feldspar-rich metamorphic rocks, such as gneisses, micaschists, and particularly feldspathic quartzites which stand out most in the scenery). Saussure eventually believed that Pallas was mentioning some type of granite when talking about rocks in the Urals where feldspar was predominating over quartz. Saussure must have read Wallerius' famous *Systema mineralogicum...* 1772-1775, according to which rocks consisting only of quartz and feldspar are classified as *Granites simplex, Species No. 199* (see Chapter II). Furthermore, Pallas' description of rocks in highly inclined beds suited Saussure's own ideas on bedded granite very well. He understood what he wanted to understand although Pallas had not mentioned bedded granite in the Urals in his fieldnotes].

[Saussure had also problems with the German mining terms used by Pallas and hence prepared a glossary of the most common ones]:

I shall intercalate here a glossary of German terms in mineralogy taken from Vogel, p. 6, 7, 8: [Rudolf Augustin Vogel, *Practisches Mineralsystem:* Leipzig, B. C. Breitkopf, 1762, 518 p.].

Gänggebirge:	*mountains with vertical or at least very highly inclined layers.*
Seigergänge:	*perfectly vertical layers.*
Donnlege:	*very inclined layers.*
Flachegänge:	*still inclined layers but less than the previous ones.*
Flötze:	*a horizontal bed.*
Flötzgebirge:	*mountain consisting of horizontal layers* (p. 54).

Addition to the glossary taken from Torbern Bergman, [Physikalische Beschreibung der Erdkugel, auf Veranlassung der Cosmographischen Gesellschaft verfasset... Aus dem Schwedischen übersetzt von Lampert Hinrich Röhl: Greifswald,

A. F. Röse, 1769], *p. 138ff.* [This book is in the catalog of Saussure's library (Saussure's Archives, MS 104, BPU, Geneva), all major libraries of the world list only the second increased and improved edition of 1780, 2 vols. in one].

Salbande oder Lasgespühl: layers between which the ore vein is enclosed or which form the country rock of the mine.

Das Dach oder die hängende Wand: in the case of inclined veins it is the bed overlying the vein, in French: le toit.

Die Sohle oder die liegende Wand: the floor of the mine or the bed underlying the vein.

Die Streichung: the direction of the vein with respect to the cardinal points of the horizon.

Die Stürzung oder das Fallen: the inclination of the vein.

Der Gangstein: the material which together with the ore fills the vein or is enclosed between the Salbanden, in French: la gangue de la mine.

Stehende: veins which are perpendicular to the horizon or at least which do not deviate from the vertical by more than 10°.

Schwebende: veins which are horizontal or at least do not deviate from the horizon by more than 10°.

Donlägige: veins which are in intermediate position between the two preceding ones.

Flachliegende: veins which are inclined less than 45° (p. 57-58).

At 12 versts from Krasnoyarsk, Pallas described rocks consisting of greenish schists which rise gradually and are crowned by steep and isolated peaks which are either granite or quartz (p. 516).

Here we have, once more, as in our country: horizontal sandy plains, inclined hills, limestones, schists, and granites (p. 65).

Volume 3. Saussure made no comments on the summary of Pallas' observations at the beginning of this volume, apparently because it was not as yet a theory of the Earth.

On Pallas' description of an iron mine, near Yeniseik, along the banks of the Tunguskaia, with unusually well-preserved tree trunks which are oriented in a S-N direction within the horizontal layer of argillaceous sand containing them (p. 308):

This position of flat-lying and in a S- to N- oriented direction of tree trunks is very favorable to the system of the author, namely the irruption of seas from the south (p. 78).

On the discovery of Pallas' student Sujef of petrified shells and, above Selakino, of a tooth and other remains of bones of elephants (p. 323):

Selakino is not in the Russian Atlas I have, but the author says on page 321 that this locality is at 620 versts below Mangasea, on the Yenisey, consequently at least at 70° north latitude. I think it is the farthest place to the north where bones of animals from India were found (p. 78).

On Pallas' description, according to the accounts of his student Sokolov, of the summit of Tschokonda (Daurien) which consists of huge and barren masses of granite, piled horizontally one above the other in a step-like fashion, and weathering to the extent of showing rounded shapes, followed by a description of the local flora (p. 442-444):

This description is very interesting. The rocks are unquestionably thick horizontal layers similar to those I observed when coming down from the Simplon. But all this flora indicates that the mountain is not very high, particularly if one considers that it is at 50° latitude north in cold Siberia. From this description, I would not give to this mountain an elevation higher than that of the Buet above sea level. What I have set in quotation marks is translated verbatim and with care to be quoted in its entirety in my work (p. 82-83).

Excerpts completed on October 2, 1778. [Saussure's reference to the southern slope of the Simplon Pass (*Voyages...*, Vol. IV, 1796, § 2127-2128) is rather vague and probably refers to granitoidal gneisses of the Antigorio Nappe belonging to the Lower Penninic Nappes. In the descent from the Simplon Pass between Simplon Dorf and Gondo, the gneisses in that area are indeed in a subhorizontal position, before plunging southward gently and then abruptly into the roots of the nappe in the Ossola Valley].

SAUSSURE'S EXCERPTS OF PALLAS' THEORY OF THE EARTH

These critical and numerous excerpts are given in short summaries by Saussure of Pallas' French text (1777) with its pagination, followed by Saussure's comments in italics with pagination of his booklets. Notes of the authors of this paper are given in square brackets.

1. On the fact that Pallas' ideas on the structure of the major mountain ranges, reached independently from those of Swedish and German naturalists, are in agreement with them (p. 4-5):

It follows therefore that all complete ranges, consisting of their three orders of mountains, are similar to each other since our Alps are also in agreement with such an organization (p. 102).

2. Granite (consisting of quartz, feldspars, and dark minerals) being the main components of the interior of the Earth excludes the idea of a central fire. This idea should please those naturalists who consider the center of the Earth to consist of a huge magnet, because magnetite, which is always micaceous and mixed with quartz, has more affinities to granite than to phlogistic minerals, limestone, or pure sand assumed by others to form the center of the Earth (p. 5-6).

Yes, but some naturalists consider the magnet as mobile [see Louis Bertrand, 1800] *and others have demonstrated that the globe has a specific gravity which is much greater by far than that of granite* (p. 103).

3. Granite may seem to have been in a state of fusion and hence a product of fire. Perhaps it does not belong to humans to understand the real cause which has thrown this enormous mass of vitreous material into the orbit we follow (p. 6).

The first part of this sentence leaves some doubts about the opinion of the author, but in the second part he becomes more affirmative (p. 103).

4. Agreement of Pallas with the opinion of the author of *Recherches sur les Américains* [C. Pauw] who said that it is a waste of time to write a treatise on the formation of stars as well as on that of rocks building our small planet because both are divine creations (p. 7).

This particular author talks nonsense because Nature has formed not only rocks but also all that exists. Therefore, if one were to follow his ideas, it would be useless to search for the origin of any kind of body. Perhaps one should quote this sentence and the approval given to it by Pallas to illustrate the difficulties he finds in explaining the formation of primitive rocks to which he applies such an approach (p. 103).

5. Granite never occurs in layers, although Pallas admits that certain granites seem to have been accumulated in layers several feet thick; but, according to him, it is an illusion and the effect of fissures which divided this rock into large parallelipipedical masses. Pallas writes that the enormous block used for the statue of Peter the Great which was 22 feet high, 42 feet long, 34 feet wide, and weighed 3,200,000 pounds could not possible have been carved out of any kind of layer (p. 8, footnote).

It sems that the granites of these low mountains are shapeless as that of the Vosges, or at least that transverse fissures tend to obscure the bedded aspect. But what about our granites with thin and continuous layers, veined granites, and so on? [granitic gneisses and gneisses]. *I would argue that the granites I have seen between Formazza and Crodo are in layers as thick as the above-mentioned block and much greater in the other dimensions* [granitoidal gneisses of the Antigorio Nappe belonging to the Lower Penninic Nappes]. *I should point out that this granite is veined, and its layers parallel to its veins, and that one cannot doubt its layered shape. Besides, nodules or kidney-shaped stones* [inclusions] *formed by infiltration into cavities can occur as I have seen in the fissures of the granite at Semur-en-Auxois and elsewhere* (p. 104). [Saussure interpreted pockets and veins of coarser granitic texture as produced by the present-day infiltration of rain water into open cavities and cracks of granites, followed by dissolution of the constituents and their reprecipitation as coarser crystals because of the quiet conditions within these cavities. Saussure used this interpretation to show that granite is a rock formed by past and present crystallization from water (*Voyages...*, vol. I, 1779, § 599-603). In reality, he was describing pockets and veins of pegmatitic character].

6. Granite resulting from a complete melting process forms the highest mountains which were never covered by layers of clays or limestones deposited by the sea; granitic mountains were since their formation high above the ocean waters (p. 7).

This is correct. I have searched in vain for calcareous rocks on top of the highest granitic peaks, but they occur in all valleys, even the highest ones. If Pallas had seen the accumulations of calcareous breccias in the Allée Blanche, at the foot of Mont-Blanc; the slates [black shales] *at Chamonix and at Argentière; and the gypsum at the Mont-Cenis, at Airolo and the Grand St. Bernard, he would have understood that they can be preserved only in valleys and not on peaks* (p. 104-105). [Saussure stressed here the effects of present-day erosion in the Alps which has destroyed the Transition and Secondary rocks overlying the granite merely on top of the highest peaks, indicating that granite was buried beneath them until the final uplift of the Alps. In modern terms, the calcareous breccias in the Allée Blanche are Triassic breccias (*cargneules*) of the root zone of the helvetic and ultrahelvetic nappes (eastern cover of the Mont-Blanc massif); the black shales at Chamonix and Argentière belong to the Carboniferous (Westphalian) of the cover of the Aiguilles Rouges massif; the gypsum at Mont-Cenis and Grand St. Bernard are part of the frontal Triassic cover of the Penninic nappes of Briançonnais and Grand St. Bernard, whereas the gypsum at Airolo belongs to the southern cover of the Gotthard massif].

7. Pallas stated that the discovery of a single limestone block on top of a granitic peak would prove the existence of volcanic fires beneath the granite or inside that rock. But this was never found. Indeed, the center of several extinct volcanoes was found to be immediately above the granite (p. 8).

I have seen in Auvergne with N. Desmarest a huge number of volcanoes, if not all of them rising through the granite as in the chains of the Puys, of the Monts d'Or; other proofs are the granitic basalts [basalts with inclusions of granite], *and the hills of the region of Padova* [Euganean Hills] *all in granite cut through by volcanoes. M. Faujas de Saint-Fond has seen with me granite uplifted by subterranean fires, and so on. Besides, if the sea had only reached an elevation of 100 toises above its present level and if the calcareous rocks which reach above this elevation had been uplifted by subterranean fires as mentioned by Pallas, these fires must have acted below the granite when they uplifted calcareous rocks sitting on granite to 400 or 500 toises as are unquestionably those of Chamonix at the mouth of the Arveyron, and many others* (p. 105). [These are Liassic limestones of the zone of Chamonix, the roots of the Nappe de Morcles that are in tectonic contact against the gneisses of the Mont-Blanc massif, near the mouth of the Arveyron river which comes from the glacier of Argentière].

8. On Pallas' note concerning the origin of the black race (p. 14, footnote).

Pallas' footnote on blacks is very poorly "digested." The author begins to write that "in spite of what M. de Pauw said, the black race is not such a simple product of the climate as he and others have assumed," and he then refutes the explanations proposed for this metamorphosis. Nevertheless, he concludes "chance may have transferred our race to Africa at a time when the high plateaus of that continent were still separated from Asia by a wide stretch of sea; the influence of such a hot climate during a series of centuries could well have changed the complexion of these transplanted humans" (p. 109).

9. On Pallas' belief that sand is produced by spontaneous decomposition of rocks, particularly granite. This is in contradiction to Buffon who derived granite from indurated sand in spite of the observation that granite and sandstone do not contain shells whereas those occur frequently in sand (p. 22-24).

It is known today that several types of sandstones contain fossil shells. With respect to the formation of sand, it is clearly shown at the springs of streams and torrents whose beds are filled by a sand of same composition as the pebbles they transport, whereas no accumulation of sand exists on the rocky mountains from which these streams flow. However, I shall not go as far as Pallas, and since Nature can generate large stones, it can also generate small ones. M. Sage was able to demonstrate the formation of quartzose sand within garden soil. Certain Alpine sandstones, so similar to granite and to quartz increase the strength of such a doubt (p. 111). [In spite of his correct field observation on the origin of stream sand, Saussure opens here the possibility of sand being formed by precipitation in sea water (as he believed for granite) and also within other sediments. The similarity he mentions between certain Alpine sandstones and granite is a typical example of his belief in the chemical precipitation of rocks in the universal ocean].

10. On Pallas' idea that decomposition of granite is enhanced by a saline principle, particularly in Finland and Sweden, and also that the salinity of the waters and the soil of all the plateaus of Asia are related to this principle of granite, which may also have contributed to the initial saltiness of the sea (p. 24).

Chemical experiments should be performed on granite of high chains. Meanwhile, I do not believe in this saline principle. My interpretation of the saline character of these high plateaus is that they were abandoned by the sea which certainly covered them previously. If Pallas' idea is correct, why are there no saline lakes in Auvergne, the Cévennes, and so on? (p. 111)

11. On Pallas' statement that the schistose band of high mountains in Russia is in general immediately covered or flanked by the calcareous band (p. 29).

The contact is not so abrupt, there are transitions (p. 114). [A reference to the Transition Rocks found and described by Saussure in the Alps (1758-1772) between Primitive and Secondary Rocks, interpreted as produced by an association of chemical and mechanical processes and formalized as such by A. G. Werner in 1796].

12. On Pallas' statement that on the west side of the Urals, the strike of the limestone chain is parallel to that of the schistose band and the main chain, whereas on the eastern side, limestone beds are locally perpendicular to the direction of the chain (p. 30).

This is rather strange and I do not understand it unless one assumes that the eastern side of the chain has primitive protuberances on which the limestone layers are resting (p. 115). [Pallas probably referred to the mass of Lower Devonian marbles and limestones marked on his map around Lake Tschernoi. These rocks trend indeed N-E among the surrounding N-S oriented metamorphic schists. Their orientation is obviously the effect of a local tectonic accident].

13. On Pallas' opinion that flintstones [cherts] are the product of a chemical change of clay beds interbedded between calcareous or ferruginous layers. On his observation of fossil corals whose outside is completely changed to agate whereas their inside remained calcareous and friable (p. 30 and fol.).

It is true that clays can change into flintstone, I have seen proofs of this process near Paris, and recently near Plombières, but calcareous rocks also undergo the same metamorphosis. Some shells show tests changed into agate, and corals, contrary to those of the author, have their inside changed to agate while their margins remained calcareous (p. 115).

14. According to Pallas, the great tertiary mountains of the west side of the Urals often reach an elevation of more than 100 toises. They form a chain that is everywhere separated by a valley of variable width from the band of calcareous rocks (p. 36).

It is likewise in our Alps: swamps at the foot of the Voirons [Frontal Ultrahelvetic nappes], *of the Jura and the Salève, perhaps accentuated by the fact that waters flowing from the mountains have eroded and formed streams. One should study the layers of the tertiary hills closest to these valleys to see if they have been eroded or if their original shape lowers naturally toward these valleys* (p. 117).

15. According to Pallas, the carcass of a rhinoceros is a decisive proof of the powerful and swift flood which transported in the past these corpses toward our glacial climate, before decomposition could destroy the soft parts (p. 38).

How is this possible? Distances should be measured on maps, movements of the waters and impacts should be evaluated (p. 113). [Saussure felt that Pallas' gigantic flood needed thorough justification of the mechanisms involved and the distances of transport (see also section 19)].

16. Pallas assumed that the high granitic mountains were at all times emerged as islands above the ocean and that the decomposition of granite generated the first accumulation of quartzose and feldspathic sands and micaceous silts from which the sandstones and shales [schists] of the primitive chains were formed (p. 40).

The author thinks that the decomposition of granite produced the schists [shales] *of the primitive mountains and thus explains the transition I have observed. But, if he explains the formation of granitoids, could he accept the formation of granite as I have proposed?* (p. 119). [The depositional transition (granitoids) that Saussure observed between granite and schistose rocks in the Alps, is described in *Voyages...*, vol. I, 1779, § 567, vol. II, 1786, § 613. Saussure's reaction to Pallas' explanation on the decomposition of granite includes also section 17. Saussure and Pallas disagreed at this stage on the formation of granites. Pallas believed that they were the oldest molten rocks on Earth whereas Saussure considered them as the first chemical precipitates in the hot universal ocean which were not exposed until the final uplift of the Alps. Pallas changed his mind in 1781. See Chapter IX, Epilogue: Pallas Afterthoughts in 1781].

17. Pallas suggests that volcanoes, now totally destroyed, uplifted and partially melted the materials forming the first mountains of the schistose band which in part extend into the layers of clay and sand of the plains, as well as the calcareous mountains whose rock is solid and generally devoid of fossils (p. 40).

The schistose band mentioned here corresponds apparently to the slates [Transition rocks] *properly speaking whereas that of the previous paragraph corresponds to the primitive schists. All this is very confusing! I would have too many things to say on this paragraph! I shall only point out that even many centuries would not erase volcanic effects while sparing perfectly regular rocks whose smallest portions are fresh and unbroken, such as the lower parts of slate mountains whose sheets although thin and soft are perfectly preserved. I shall also point out that calcareous mountains could not be the products of volcanoes, indeed their thin and regular layers of non-calcinated stones, virgin so to speak, carry no traces whatsoever of an igneous origin. This idea of Lazzaro Moro has been rightly abandoned. Finally these mountains do not appear more dislocated than those following them, only their beds are more inclined* (p. 119). [There is no real confusion in Pallas' ideas, but an ackward statement on contact metamorphism. He said, "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." In other words, 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. But this was not clear in the French version which has omitted part of the last sentence (See our footnote No. 25 to Pallas' theory). Furthermore, Saussure was apparently confused by the use of the German word "*Schiefer*" for both shales and schists (see Chapter II on this problem of terminology). For a discussion of the refutation of Moro's theory by Saussure, see Carozzi and Newman, 1990].

18. On Pallas' opinion that the activity of volcanoes is probably responsible for the uplifting of huge masses of limestones in Europe which were originally rocks formed by corals and banks of shells (p. 41).

This idea came to my mind when I was on top of the Cramont, but I subsequently considered it as doubtful because of the highly regular aspect of the layers expressed by their dip and the direction of their planes [strike], and because of the total lack of traces of these uplifting fires, although I had thought to assume elastic fluids acting independently of heat. However, since I have elsewhere almost unquestionable proofs of large local uplifts, I shall not entirely eliminate this last hypothesis; I put it only among the doubts (p. 120). [For the first time to our knowledge, Saussure stated here clearly that the orogenic mechanism he proposed, that is, earthquake-generating explosions of elastic fluids enclosed in caves of the earth's crust, was entirely independent of heat. It is too bad that he did not explain his large local uplifts].

19. On the idea of Pallas and A. de Jussieu that the ferns and other exotic plants found as imprints in the slates (black shales) of Europe were brought by a flood which came from the south or the Indian Ocean (p. 44).

As far as I am concerned I shall never be convinced that the ferns of the Rivière de Giés originate from the Indian Ocean when I take into consideration their great amount at that particular location as well as in England and in Switzerland. When I consider the small size of the inhabited plateaus of Pallas, I do not understand that they could provide so many plants and that they could reach their present location in such good condition. How could large leaves similar to those of the banana tree, perfectly healthy and well stretched, have travelled such a distance? Furthermore, do the teeth of elephants and hippopotami of Tuscany also come from the southern part of Tibet or Africa? In my opinion, absolutely not. Although I have great difficulties explaining changes of climate, I would rather think that elephants were native under a latitude which is now 44° and the night jasmine under 45° rather than believe that bones and leaves were transported by waters across all the asperities of *the world for distances of at least 400 to 500 leagues* (p. 121). [Saussure is obviously opposed to Pallas' gigantic flood which originated from volcanic activity in the southern seas and swept across the northern hemisphere, including Siberia, and as far as the Arctic Ocean. The assumed deposits of this flood are in fact of different geological ages which were not known at the time. The reference to Jussieu pertains to the Carboniferous (Middle Stephanian = Uppermost Pennsylvanian) flora of the black shales interbedded with coal at St. Chamond, near Lyon, France. The teeth of elephants and hippopotami of Tuscany belong to the Villafranchian (early Pleistocene) famous vertebrate fauna of the intra-apennine basins of Mugello (near Bologna) and Val d'Arno (near Florence) which consists of *Elephas, Mastodon, Equus, Leptobos, Hippopotamus, Cervus,* and so on. The night jasmine called in French *arbre triste* is in reality a shrub called *Nyctanthes arbortristis,* of the family *Oleaceae,* native of eastern India which bears fragant flowers which bloom and fall in the night.]

20. On Pallas' causes of his gigantic flood, namely that the masses of water were set in motion by the eruptions of volcanoes which built the archipelagoes of Indonesia, Philippines, and Japan and which are raised as on some gigantic vaults of a common furnace (p. 44-45).

Seen from a distance, this hypothesis appears very plausible, but in reality it does not withstand a serious examination. It should be recalled that, according to the author, there are no volcanic centers inside the granite, that they occur only beneath the schistose band, and that this band consists of broken and fissured beds. Regardless of how continuous such a band is, how could a subterranean fire uplift these rocks in one single mass so as to form beneath them huge bubbles? How huge should these volcanic bubbles be so that they could displace volumes of water capable of overflowing the highest granitic plateaus? This is impossible to visualize. Indeed, subterranean fires by bursting through overlying beds would generate in the sea a local and instantaneous uplift because the waters would instantly reoccupy the space made by the subterranean fires and would penetrate even deeper, taking the place of the consumed materials. The assumption of such a continuous vault uplifted as a single mass to a height sufficient to allow the ocean waters to flow over the highest mountains of Tibet is really an absurd hypothesis, because if the crust breaks up while bursting, no uplifting occurs. My hypothesis of an undulatory movement of the surface of the Earth, as absurd as it may appear, is somewhat more acceptable. See next comments (p. 122). [Saussure's reference to his idea of undulatory movements of the earth's crust relates to his concept of orogenic events (1775-1778), reached after his study of the Vallorcine conglomerate and others, which he visualized as worldwide seismic shocks increasing in intensity with time and immediately followed by floods or *débâcles*].

21. On Pallas' global ideas that the shape of the major oceanic embayments and seas, the southern promontories of the Asian continent, and other characteristics of the coasts of South America were produced along the path of the gigantic flood which originated in the Indian Ocean (p. 46).

In my hypothesis which says that the sea covered everything in the past and that it withdrew by means of great shocks and débâcles, I open the great receptacle in the North and also explain everything, including embayments and promontories. I explain also the rising of the sea over continents and therefore the transport and burial of plants and bones because I visualize several débâcles, the last occurring at the time when the seas had already been appreciably lowered and consequently left continents exposed. Therefore, I abandoned the idea of irruptions of water because of the impossibility of volcanic bubbles discussed in the previous comments. The author said at the end of p. 42: "The volume of water required to reach or to overflow the elevation of the highest mountains over the entire surface of the Earth could hardly find enough space in the inside of that sphere even it were assumed to be entirely empty by means of caves." But I shall answer that he himself creates instantaneously huge caves. His volcanic bubbles which displace all the waters and make them rise above Tibet should be as large as the caves I need. It is easier to visualize a cavern previously formed at the bottom of the sea by collapse of its walls or by other causes than the formation of a volcanic bubble by means of fragile and molten materials, and so on (p. 123).

Excerpts completed on November 17, 1778. [This last comment is of greatest interest as a confirmation and amplification of the study of the evolution of Saussure's thinking on a theory of the Earth derived from his unpublished field notebooks (Carozzi, 1989). It is Saussure's only written statement found sofar that the universal ocean withdrew by a succession of possible worldwide seismic shocks and débâcles, a concept we had intuitively reached through analysis of his notes. Saussure described only the most important and last flood or *débâcle* which followed the final uplifting of the Alps. He interpreted it as the draining of oceanic waters into caves — located on both sides of the Alps — inside the Earth's crust. Thus he explained the Pleistocene record of tills and gravels and the transport of the huge blocks of primitive rocks (erratic boulders) scattered over the Swiss Plateau as far as the Jura and over the northern plains of Italy.

It is quite interesting that Saussure's reaction to Pallas' idea of a gigantic flood, triggered by volcanic activity in the southern seas, and its eventual disappearance into a cave toward the North Pole, prompted Saussure to embrace a global view of his own. Consequently, Saussure's worldwide *débâcle* following the final Alpine orogeny disappeared also into a northern receptacle (cave); this débâcle shaped also the morphology of the embayments and promontories of major continents by flooding them, by reworking and burying plants and animals which lived on their exposed surfaces since the universal ocean had lowered appreciably and was on its way to present-day boundaries. This reaction coming from a modest and naturally posed man shows how infectious Pallas' ideas really were in the eighteenth century].

Excerpts from Saussure's "Loose thoughts to be used in my book on mountains"

From a systematic list of ideas divided into 23 subject matters we present only those which clearly reflect the influence of Pallas. Saussure's customary scientific honesty appears in his willingness to investigate the positive aspects of Pallas's ideas or to test to which extent they could explain certain facts better than he himself could, even in his incorporatation of some of Pallas' concepts in his own worldwide speculations. [Saussure's ideas are paraphrased and condensed instead of given *verbatim*.]

Introduction to my Book

I shall start with a foreword in which, like Pallas, I shall mention the universality of several systems, requesting that they not be abstracted, criticized, or praised again as has been done so many times. All these ideas have been repeated and presented in a thousand forms. Although these systems were all useful to me, my twenty years of field observations have been more important. It does not really matter who was the first to talk about the effects of water, whether it was Buffon, Whiston, Thales, and before him the Egyptians whom Thales seems to remember. I shall praise or refute authors of systems only when I cannot avoid it. In fact, in this chaos of systems, glory is not bestowed on inventors [persons with new ideas] but on those who gather previous ideas (p. 7). [This sentence, expressing a rare burst of anger from Saussure, most probably against Buffon, is crossed off in the notes.]

On the Question of the Formation of Granite by Chemical Precipitation at the Bottom of the Universal Ocean

At that time, the waters did not contain any organisms; no traces of them have been found. If there had been any, they would be found cemented inside granites together with the large feldspars and the finest needles of schorl [tourmaline] which have not been affected by pressure because in a perfect fluid pressure is uniform [hydrostatic]. Mountains [deposits] formed immediately after the primitive ones contain a very small amount of marine animals. Pallas has seen it and I have also. The overlying rocks [secondary] contain a greater amount of organisms, and finally, the lowest plains [tertiary rocks] and the present seas display the greatest quantity. In summary, the amount of animals in the universal ocean has continuously increased from the time of formation of granite to the present (p. 2).

I can even demonstrate the immensity of the first universal ocean and the fact that it was devoid of shorelines by means of a new idea, that is, the absence of rounded pebbles inside primitive mountains. At Livorno, beds deposited today are a mixture of rounded pebbles and marine organisms because they are formed along a shoreline. Since there are no rounded pebbles inside primitive mountains, they were formed in a sea without shorelines. Later on, after the first phase of uplifting of the primitive mountains and the retreat of a portion of the waters, shorelines began to exist. The first ones leaning against the primitive rocks are filled with rounded pebbles [Vallorcine Conglomerate, see Fig. 1], so it is in mountains formed during subsequent times of uplifting (p. 8) [secondary mountains with intraformational shelly breccias, Mornex Conglomerate, last débâcle].

Origin and Evolution of Life. Proposal for a New Orogenic Theory

The universality of the waters over the entire surface of the Earth is not so absurd as stated by Pallas. The formation of granites compels us to accept this idea. However, it raises the question of the origin of terrestrial animals and plants, regardless if one accepts the concept of germs (Palyngenesis of C. Bonnet) or a *Deus ex machina* creation (p. 6) [preformation].

With respect to the development of germs, I wish to say that if we accept germs [preformation] instead of spontaneous generation of organized beings, it is for the purpose of carrying physical explanations as far as possible, and not to dispense with the creative power since germs by themselves demonstrate such a power. The most outspoken advocate of the concept of germs [C. Bonnet] has very well shown that the known forces of Nature are insufficient to produce them.

On this subject of germs, I shall notice that the system of Pallas which assumes granitic islands scattered in the immense ocean seems to avoid the creation of terrestrial plants and animals since they were always able to survive on such islands. But I say that this system merely postpones the problem because such islands could not have existed for ever. Indeed, they must have been battered by the waves of that immense ocean and washed by the heavy rains generated by the almost entirely aqueous globe. Therefore, these islands could not have been eternal, in fact they could not be very old [Saussure's idea of the final uplifting of granite during the last Alpine orogenic event]. One might suggest that terrestrial animals could have lived on one particular granitic island, and that after its destruction or disappearance in the ocean, these animals swam to another one. But this migration by island hopping merely postpones the problem one more time and would certainly not satisfy Pallas (p. 11-12).

The only way to postpone the difficulty is to assume that the sea undergoes a very slow and progressive movement, gaining on one side what it loses on the other, and that living beings gradually follow this movement. But how does one explain that the bottom of the ocean was dry while waters were covering the Cordilleras?

Perhaps by a combination of the action of subterranean fires and sinking processes which would elevate land here and lower it there by some kind of vermicular or undulating movement. Indeed, the centrifugal force responsible for the diurnal movement is not sufficient to lift the waters above the top of mountains, as once believed, because at present we find very high mountains along the equator which are not only completely dry but also the highest mountains on Earth.

One could build a very attractive system based on this vermicular movement; one might search for its periodicity. If the movement were slow, nothing unusual would happen, if it were sudden, it could explain gigantic floods, débâcles, and so on. For instance, a sudden uplifting of the Cordilleras would account for the violent débâcles coming from the south postulated by Pallas. If it is true that the sea level in the North Sea is lowering according to Swedish naturalists, and that it is rising in the Adriatic according to A. Fortis, this would mean that the northern portion of the globe is in turn rising today. Only barometric observations can confirm or destroy such a hypothesis. If the northern part of the globe is indeed presently rising, then the problem would be solved (p. 12, 13). [Saussure's hypothesis of a global undulatory movement of a flexible earth's crust is an anticipation of Haarmann's "Oszillationstheorie" of 1930 (see also Van Bemmelen, 1964). The related interpretation of the rising of Scandinavia foreshadows the concept of isostatic uplifting of shorelines of the Gulf of Bothnia due to the unloading of the Arctic icecap, demonstrated in 1810 by C. L. von Buch on the basis of markings engraved in rocks by A. Celsius].

On Mountains in General and on the Relationship between Primitive and Secondary Mountains

The explanation proposed by Pallas on the uplifting of secondary mountains by volcanic action is completely absurd because it can be easily shown that secondary mountains cannot be uplifted without moving the primitive ones together with them (p. 4, 7). This is demonstrated by the parallelism between transitional schistose rocks and the underlying layers of granite on which they rest. This proves at the same time that sheets of granite are real beds and not accidental fractures or fissures (p. 15).

Very little has been done until now on the direction of mountains; they seem to vary a lot in their substratum, in their branches, and in elevation. Concerning eroded coasts and promontories extending toward the south, they seem to originate (and I agree with Pallas on this matter) from great water irruptions coming from such areas.

However, one should distinguish between complete and incomplete mountain chains, some have 4 orders of mountains, others only 3, 2, or 1. The Alps, the Urals, and various chains of Sweden are complete whereas the Apennines are incomplete having only 2, 3, and 4, and the Vosges only 1, 3, and 4 orders. Therefore, when comparing one chain to another, they should be of the same kind for the procedure to be valid as was done by Pallas who found a perfect agreement between his observations and those of Swedish and German naturalists (p. 9).

On Floods (Débâcles) and Caverns inside the Earth

In my *Excerpts* I have explained the reasons for my rejection of Pallas' idea of a catastrophic flood generated by volcanoes in the Indian Ocean and of the related transport of foreign animals and plants over thousands of miles. I would rather consider changes of climates (p. 7).

According to Pallas a revolution consists of the irruption of great volumes of water followed by their absorption in subterranean caves. He has very well explained in this manner the fossils woods [petrified tree logs oriented N-S found by Pallas in Siberia and the Urals]. Such irruptions could even help to understand the changes in the nature of the deposited rocks because waters may have extracted from the Earth materials which combined with those of the caves and produced new mixtures (p. 3, 4).

What great caverns? What receptacles? [Pallas postulated a large cavern under the Arctic Sea for the final engulfing of his gigantic flood. Saussure was not entirely opposed to this idea — in fact, he proposed some similar caves in his Excerpts (p. 123) — although in his theory of the formation of the Alps the caves engulfing his successive débâcles were located on both sides of the Alps. At any rate, it seemed reasonable for Saussure to raise here the fundamental question of the very existence of such caves.]

Experiments on gravity demonstrate the existence of caves within the Earth because the density of the globe is lower than that of mountains. I shall proceed to present several calculations [not reproduced here, but perfectly correct] of the volume of a spherical cavern capable of engulfing oceanic waters reaching respectively 1/4th of a league, 1.5 leagues, and 2 leagues above present sea-level [a league = 4.25 km]. In the case of 1/4th of a league, the cavern would have a diameter of 300 leagues which is 1/10th of the Earth's diameter. This situation is comparable to bread with pores, or more precisely of a loaf of bread 5 inches [13.5 cm] in diameter, a cavity being 6 lines in diameter [1.2 mm]; this is not an impossibility but a very common occurrence. For 1.5 leagues, the cavern would have a diameter of 430 leagues, that is 1/7th of the Earth's diameter, and for 2 leagues, the cavern would have a diameter of 600 leagues, that is 1/5th of the Earth's diameter. Hence, such caverns are perfectly conceivable because a cavity of 600 leagues in diameter, or several caverns totaling that size, would only represent 1/125th of the volume of the present globe. Furthermore, a portion of the waters may convert to earths or at least combine with earths, and the size of the cavities may be accordingly reduced to absorb the remaining liquid (p. 4).

On the Distribution of Large Blocks and Rounded Pebbles by the Final Débâcle on Both Sides on the Alps

It is a remarkable fact that the large blocks and rounded pebbles [Pleistocene erratic boulders and glacial outwash gravels] are less widespread on the southern slope of the Alps than on the northern one, a situation which could favor Pallas' idea that the irruption of waters came from the south. The blocks of the southern slope would be those which fell back when the lowering waters pulled them down. Our rounded pebbles certainly originate from very far, several types are almost certainly ultramontane. However, it is very strange that this gigantic current of water coming from the south could have crossed the Alpine chain and then be stopped by the Jura mountains, or at least that it did not produce appreciable effects beyond the Jura. One could say that the Alps broke the impetus of the flood so its remaining strength was not sufficient to transport over the Jura the blocks detached from the Alps.

The irruption of the sea that according to Pallas came from the south would also explain the alleged observation of Buffon that slopes of mountains are steeper on their southern sides than on the northern ones (p. 13, 14).

CONCLUSIONS

Pallas' theory appeared at a time when Saussure was attempting to write one of his own. It was therefore both exciting and disturbing for Saussure. Exciting because he found in Pallas many ideas over which he had pondered for many years, but it was perhaps a bit disturbing because Pallas' theory was quite different from his own. For instance, he did not accept Pallas' explanation of the origin of granite and made it quite clear what he believed. On the one hand, he chose to reject the huge flood triggered by volcanoes coming from the south and proposed that a change of climate would better explain the presence of "animals from India" in Russia (he shrewdly pointed out that too many animals were supposed to come from these foreign countries which according to Pallas' theory represented only a small land). On the other hand, however (in his last section mentioned above "On the distribution of large blocks and rounded pebbles...,") he toyed with Pallas' ideas of a flood coming from the south.

Saussure reacted quickly to a flaw in Pallas' theory, which appears to us the most important, namely Pallas' description of the Ural Mountains consisting of feldspathic quartzites in vertical layers in the axial chain whereas he had mentioned in his foreword to Part III of his *Reise* (1771-1776) that the highest chain of the Urals consisted as in other major mountains of granite.

It is quite obvious that Saussure respected Pallas for his many excellent descriptions and observations, for his global approach to the geological history of the Earth, and for his disdain of repeating what others had said before. His reaction also shows how important Pallas' theory of a flood was at the time because it was capable of solving many unrelated problems as a unifying theory would. Alexander von Humboldt apparently called it a "bombshell" (see Arthur Stössner's evaluation of Pallas in Chapter V).

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CHAPTER V

REVIEW OF SUBSEQUENT ACCOUNTS OF PALLAS' THEORY

ARCHIBALD GEIKIE

Geikie (1897, reprint 1962, p. 178-181) wrote that the Empress Catherine II commissioned the Academy to organize an expedition of the Russian Empire and that it was entrusted to Pierre Simon Pallas. Geikie reported on Pallas' memoir on the formation of mountains... 1777, p. 21-64, the following:

"The highest mountains are composed of granite, with various schists, serpentine, grits, and other bedded masses in vertical or highly inclined positions. These formed his Primitive band, and in his opinion were older than the creation of organized beings, for no trace of organic remains was to be found in any part of them.

The primitive schistose band of the great chains is immediately succeeded by the calcareous band, which consists first of solid masses of limestone, either containing no marine productions or only slight traces of them. The thick beds of limestone are placed at high angles and parallel to the direction of the chain, which is also generally that of the schistose band. As they recede from the line of the mountains, the limestones rapidly sink down into a horizontal position, and soon appear full of shells, corals and other marine organisms. These upheaved limestones form the Secondary mountains of Pallas. A third series of rocks, which seemed to him to be the record of some of the latest revolutions of the globe, consists of sandstones, marls, and various other strata, forming a chain of lower hills in front of the limestone range. To this series of deposits he gave the name of Tertiary mountains. These geological terms, thus proposed by Pallas, were not of course used by him in their more precise modern definition. We know, for example that his Tertiary mountains consisted of the younger Palaeozoic sediments which are now called Permian, and with these ancient formations he included the much younger sands and clays that enclose the remains of mammoth, rhinoceros and other extinct mammals. [On the west side of the Urals, Pallas' Tertiary mountains are in fact hills of Pleistocene outwash gravels with mammoth bones resting on Permian limestone. On the east side, they consist of Jurassic, Cretaceous, Tertiary, and Pleistocene outwash gravels with abundant mammoth bones in the Siberian plain.]

The main value of his observations lies in his clear recognition of a geological sequence in passing from the centre to the outside of a mountain-chain. He saw that the oldest portions were to be found along the axis of the chain, and the youngest on the lower grounds on either side. He recognized also that the sea had left abundant proofs of its former presence on the land, he thought that its level had never been more than 100 fathoms higher than at present, and he supposed that the elevation of the mountains had been caused by commotions of the globe."

ARTHUR STÖSSNER

In 1900 (p. 1-53), Stössner gave an excellent description of most of Pallas' geological works: his theory of the Earth (1777); his article *De ossibus Sibiriae fossilibus* (1769) where Pallas refuted Gmelin's idea of a S-N flood that transported tropical animals to Siberia; his article *De reliquiis animalium exoticorum* (1773) where he wrote that only a violent flood could have transported animals (not decayed) from the hot climates of India to the frozen grounds of Siberia; his periodical entitled *Neue nordische Beyträge* (1781-1796); his observations made during his first expedition (1769-1774), and his second one (1793-1794).

Stössner referred not only to Pallas' change of mind in regard to the flood (Stössner, p. 27-29) but also toward the origin of granite. Indeed, in the second volume of *Neue nordische Beyträge* (1781, p. 367) Pallas wrote that granite was a product of crystallization whereas in 1777 he had favored the opposite view (Stössner, p. 10). [This is correct. See our translation of Pallas' opinion on the origin of granite in the Epilogue of Chapter IX.] Stössner emphasized that Pallas' greatest impact on his contemporaries was nevertheless his theory of a huge flood that was capable of solving various unrelated problems at the time. Besides transporting tropical plants and animals to the north, this flood formed large bays in various oceans; it explained the origin of the shallow North Sea; the asymmetrical slopes in the mountains of Asia, and the Cordilleras; the erosion of the Finnish plateau, exposing granite; the fossiliferous rocks of the Baltic Shield; the occurrence of huge granite boulders resting on secondary mountains; the pointed southern projection of the continents; and the accumulation of petrified wood in some areas on Earth. Stössner stressed that almost every naturalist of his time had to reckon with Pallas' theory: Jean-André Deluc, H.-B. de Saussure, Leopold von Buch, Georges Cuvier, and others (Stössner, p. 30-35). Alexander von Humboldt is supposed to have said that Pallas' theory was like a bomshell thrown in the middle of people who wrestled with unsolvable problems (Stössner, p. 36-37).

KARL VON ZITTEL

Zittel (1901, reprint 1962, p. 50-52) wrote: "John Michell had in 1760 published in the *Philosophical Transactions* a series of observations on earthquakes and mountain-structure. This paper was accompanied by an ideal section through a mountain-system, showing a central core composed of the crystalline massive rocks, on either side a succession of uplifted and upheaved strata covered in their turn by younger, slightly tilted, or horizontal deposits composing the neighbouring plains. Michell, however, did not draw any general conclusions. Pallas was enabled from his wide experience to fill in the details of Michell's skeleton plan of a mountain-system.

According to Pallas, granite forms the core of all great mountain-systems. It is covered by unfossiliferous schistose rocks of various kinds, serpentine, porphyry, etc. These rest against the granite in highly-tilted or vertical positions, and are themselves succeeded by argillaceous schists and shales, and by thick masses of limestone containing marine fossils. The shales [in fact schists] and limestones have highly-tilted positions where they occur in the inner parts of a mountain-system, but become less tilted and horizontal in the outer portions, the number and variety of the fossils at the same time increasing. The low hills and plains are composed either of sandstone, marls, and red clay with stems of trees and twigs of land plants, or of loose material, with the bones of large land mammals. Pallas examined the mammalian remains with great care. He proved the astonishing frequency in the occurrence of mammoth, rhinoceros, and bison in the Siberian plains, and described a rhinoceros corpse with hide and hair complete, imbedded in the sand and pebbles on the bank of the Willui river. He also stated that great accumulations of sand and sulphur occur in the schistose zone of rocks, and that the decomposition of these materials gives origin to volcanic disturbances, which however affect only the rocks above the schistose zone and the granite. [According to Pallas, the schistose rocks are affected.]

The primeval ocean of the globe, in his opinion, never stood more than 100 fathoms above the present sea-level, so that the granite core of the mountain-chains [including schistose rocks which belong to mountains of first order] could not have been covered by it. All mountain-ranges composed of schists, limestone, and younger formations, or, as Pallas called them, the mountains of the second and third order, owed their upheaval to volcanic force [schists do not belong to mountains of second order, Zittel meant shales]. The schist mountains had originated before the creation of living creatures; then the limestone ranges rose above the primeval ocean, and some of these, such as the Alps, in relatively recent periods. The mountain of the third order were due to the last volcanic eruptions. The upheaval of mountain-chains was always accompanied by violent ground-tremors and by other disturbances of the earth's surface. Great cavities formed in the earth's crust and filled with sea-water; or, sometimes, portions of the continents were devastated by floods. In illustration of this, Pallas said that at the outbreak of volcanic action in the Indian Ocean and South Seas, '*which two seas seem to occupy a position above one common volcanic arc,*' the waters of the Equator were forced towards the Poles, and carried northward from India the plants and animals that now lie buried in the loose gravels of the

Siberian plains. This was the explanation he gave of the occurrence in such remarkable number of bones of mammoths, rhinoceroses, and buffaloes in Siberia.

Although his explanation and many of his opinions about volcanoes were erroneous, there can be no doubt that Pallas was an accurate observer, and that his broadly conceived delineation of the surface conformation, general sculpture, and physical characters of a huge and hitherto untravelled territory, conferred an inestimable boon on the struggling natural sciences.'' [This area had been visited before by travelers such as Gmelin and others].

F. D. ADAMS

Adams (1938, reprint 1954, p. 387-380) wrote: ''Under the auspices of the Czarina Catherine II of Russia, Pallas traversed almost the whole of Asia and made a study of the greater part of two of its greatest mountain ranges, the Urals and the Altai. With the knowledge so gained, together with that garnered by other observers from their studies of the Alps, Apennines, Caucasus and other ranges, Pallas says that it has been shown that the highest mountain ranges of the world are composed of granite. This rock is massive and contains no organic remains. Accompanying and usually bordering it are a great variety of rocks (which geologists in modern times designate as crystalline schists), these are in the form of beds, standing vertical or inclined at high angles, and which often enclose ore deposits. Like the granite these rocks contain no fossils and were undoubtedly brought into being before there was any life on the earth... In the mountain ranges, the belts of crystalline schists above mentioned are succeeded and overlain by calcareous rocks forming another band or strip on either side of the axis of the range. These calcareous rocks constitute the Secondary Mountains and have a steep dip away from the axis of the range, which dip flattens out to a horizontal attitude in receding from the range and often gives rise to great plains, as in the case west of the Ural Mountains. Overlying the 'Calcareous Border,' which is of marine origin and often rich in fossils, is a great series of clays and marls which constitute the Tertiary Mountains, and which are excellently seen along the whole length of the Urals on their western side. These also are often filled with fossils.

In the original ocean the summits of the *Primitive Granite Mountains,* which were formed when the world was created, protruded above the waters as lines of islands. The disintegration of the granites under the attack of the ocean waters gave rise to accumulations of quartzose, feldspathic and micaceous sands which hardened into crystalline schists which lie upon the slopes of the granite ranges. Later there were deposited from the ocean the calcareous rocks of the *Secondary Mountains* and still later the clays and marls of the *Tertiary Mountains.* [The Tertiary mountains, Pallas said, are deposits of material transported from India by huge floods.]

While all these rocks of the threefold succession were being laid down, there were accumulated in many places on the sea bottom great bodies of iron pyrites formed from ferruginous materials washed into the sea and which then became mingled with great quantities of decomposing remains of various animals which lived in the sea. [Pallas said that the sea carried to the coasts highly inflammable, iron-rich materials derived from the decay of many animals and plants which lived in that sea, including the remains of these bodies, p. 66.] These accumulations of pyrites taking fire gave rise to the volcanoes which broke out in various parts of the world and are still active in so many places. It was the explosive forces developed in these volcanoes that causes the fracturing and upheaval of the strata seen in the series of crystalline schists as well as in many parts of the Secondary and Tertiary Mountains, in fact, Pallas says, the explosions from these bodies of pyrites were probably the cause of the elevation of the whole chain of the Alpine Mountains, composed largely of calcareous rocks formed from the remains of corals and shells like those which are accumulating on the sea bottom of the present ocean, and where the associated clays commonly contain a great abundance of pyrite...

In his opinion, the sea never ascended high enough to cover more than the little limestone hills which rise from the plains-that is to say, not to an elevation of more than 100 toises (i.e., 640 feet) above sea level; all the limestones in the Alps which occur at a greater elevation than this have undoubtedly been upheaved by the force of subterranean eruptions."

JOHN C. GREENE

Greene wrote (1959, p. 72-73): "His [Pallas'] *Observations on the Formation of Mountains,* published in 1777 and again in 1782, provided a confirmation of the findings of Arduino, Saussure, Lehmann, and other observers [not Saussure]. In Russia, as in western Europe, the substratum proved to be granite, followed successively by schistose formations, sedimentary rocks bearing marine fossils, [actually massive limestones first without fossils, or at least very few, in vertical position, and then in horizontal beds full of marine fossils] and alluvial strata filled with 'elephant bones,' tree trunks, and similar debris. In explaining the genesis of these formations, Pallas made liberal use of both fire and water. He had no theory of the origin of the granite core of the earth or of the primeval ocean which he thought must have covered all but its most elevated peaks and plateaus. He was sure, however, that the formation of the schistose mountains and the fracture and elevation of the calcareous strata could be explained by assuming extensive volcanic activity in every quarter of the globe at some early period in its history. Traces of these volcanoes were hard to find, he conceded, but new facts were coming to light every day, and the volcanic hypothesis explained the apparent phenomena better than any other.

'These operations of volcanoes,' he declared, 'have continued in different places, especially in the vicinity and at the bottom of the seas, up to our own day. It is by their agency that new islands have been seen to rise from the depths of the ocean; it is probably they which raised all those enormous calcareous Alps, formerly coral rocks and beds of shells, such as are still found today in the seas which foster these productions'.

Deluges played a part in Pallas' version of earth history, too. Noting that the slow and regular processes of erosion, deposition, and solidification would require millions of years to build the rock-ribbed continents at the expense of the sea, Pallas sought a more rapid and efficient cause. Suppose, he conjectured, that a great submarine eruption off the coast of China should have elevated the Japanese and Philippine Islands above the surface of the ocean and sent a series of tidal waves rolling northward and westward into Asia and Europe. Such a flood might well have swept elephants, rhinoceri, tropical plants, and much other debris into northern Europe and Asia. Attested by Scripture and by the traditions of every nation, the Deluge provided, said Pallas, a far better explanation of the facts of natural history than Buffon's supposition of the formation of the continents by ocean tides and currents."

V. V. Tikhomirov

Tikhomirov (1969, p. 370) stated that Pallas, "mainly on the basis of his investigations in the Urals, established that the core of mountain ranges usually consists of granite, against which, along the flanks of elevations, are inclined, first, masses of slate [schists] and then marine limestone sediments [two types of limestones as mentioned above]; marginal foothills consist of less consolidated reddish sandstones, marls and clays, containing the remains of terrestrial animals and plants. Pallas thought that the origin of such mountains proceeded in the following way: the oldest rocks are granites that rose as primeval islands from a primary sea; together with barren slates [schists] they form the Primary formation; the slates [schists] are younger than the granites because they were formed as the result of a disintegration of the granites. The limestones, which contain fossils [not always], are still younger and form a Secondary formation. Unconsolidated rocks of the foothills distinguished as a Tertiary formation are youngest, their accumulation resulting in a filling in of depressions with sediments. The uplift of the mountain range intensified by volcanic processes was accompanied by a retreat of the sea. This caused the inclination of the beds, steepest with the oldest rocks [This is a misrepresentation of Pallas' theory]. This fact well known to the geologists of our time, was not generally recognized in the middle of the eighteenth century, inasmuch as, owing to an absence of geological maps and sections of folded areas, it was very difficult then to establish any regularity in the change of the inclination of beds. These ideas of Pallas were a continuation of Lomonosov's ideas, which stressed that 'the nearer the seams are to the ore mountains, the steeper the angle they make with the horizon'!"

VASILIY A. ESAKOV

Esakov (DSB, 1974, p. 283-284) stated: "Pallas and his companions journeyed from St. Petersburg to Moscow; crossed the Volga at Simbirsk (now Ulyanovsk); and explored the Zhiguli Mountains and the southern Urals, the steppes of western Siberia and the Altay, Lake Baikal, and the mountains of Transbaikalia. The easternmost regions visited were the basins of the Shilka and Argun rivers. On his way back to St. Petersburg, Pallas studied the Caspian depression and the lower reaches of the Volga...

Pallas offered a paleogeographic interpretation of fossil animal remains found in the frozen strata of Siberia, although he was influenced by ideas that explained these phenomena in terms of the sudden catastrophic incursion of oceanic water from the south...

In his opinion, granite constituted the skeleton of the earth and its nucleus. Emerging after some time in the form of marine islands, the granite appeared framed with slate [Pallas did not say this], the product of the disintegration of the granite. Limestones containing organic remains [not those close to the schists] and constituting a Secondary formation are even younger. The friable rocks of adjacent foothills were separated out into a Tertiary formation. The raising of the mountains and the receding of the seas occurred, in Pallas' opinion, as a result of volcanic processes. These processes caused the inclined position of layers, especially of the steep position of the most ancient rocks." [This is an unsupported repetition of Tikhomirov's misrepresentation of Pallas' ideas.]

FOLKWART WENDLAND

Wendland (1986, p. 75-81) reproduced Pallas's theory of the German edition of 1778 in a slightly edited form. He added comments on Pallas' geology (which are given below in translation), followed by some historical remarks on how Pallas' theory fits into the eighteenth century. He also explained Pallas' change of mind about the flood transporting animals from India to Siberia and about the origin of granite. He documented the fact that Pallas had less than fourteen days to prepare his talk for the Academy of Sciences. Wendland's comments on Pallas' geology in four parts were changed into four topics.

Topic No. 1 [Origin of granite]: "Granite — always without fossils — forms the most important part of our Earth, both at its surface and in its interior. It is possible that granite was originally a hot melt, at least Pallas considered it *umgeschmolzen,* [remelted]. At the same time, he refuted the opinion of a central fire but did not exclude a magnetic core. The highest elevations of all granitic mountains were never covered by the sea; they always formed islands. Decomposition of granite produced material for new rocks, in particular schists *(Schiefergebirge).*

Pallas then tried to support this thesis by a description of the distribution and geomorphologic arrangement of granitic mountains in the Russian Empire and even beyond its frontiers. He relied first on personal observations and then on 'reliable' accounts made by his contemporaries. He believed that these mountains were not only watersheds but also frontiers between peoples, lands, and continents (see Stössner 1900, p. 19). He first described the Caucasus and the mountain chains surrounding the Caspian Sea, the Urals, the Altai, Sajan, Stanovoijh, and the mountains and deserts of Central Asia between Russia and the Tibet. In his rather voluminous description, he refers — as was the fashion of his time — both to geological, geomorphological, and geographical observations and facts so his representation turned out a little bulky. Two points are repeated: 1. how are mountains connected? In that respect, he refuted Bourguet's theory that mountains represent some kind of ribs fixed to a common spine. [Pallas mentioned that Swedish naturalists referred to the concept of such ribs (p. 19); furthermore, Bourguet compared mountain chains to the walls of a fortification with salient and reentrant angles.] Instead Pallas thought that they spread out from a central point. Pallas is supposed to have been led to Buache's views through personal contact with Johann Gottlob Lehmann. However, this meeting could only have taken place before Lehmann's settling in St. Petersburg in 1761 because Lehmann was already dead when Pallas himself arrived in St. Petersburg. The influence of Buache on Pallas is also evident in his description of branching-off mountain chains. He repeated Buache's error when he talked about mountain chains that 'hold together the inhabited world.' (Stössner, p. 17-19). Pallas used the concept of 'plateau' introduced by Buache as the converging point of watersheds, in the sense of *hoches Tafelland* (high plateaus). Alexander v. Humboldt accepted this concept in the same sense (Stössner, p. 15).

He considered as reality that submarine mountains in oceans were the continuation of continental mountains, which as mid-oceanic ridges have played such an important role for the formulation of the modern hypothesis of plate tectonics. [Buache's proposed submarine mountains were running in a transverse fashion across oceans, connecting mountains from one continent to another. Mid-oceanic ridges were unknown at his time and this assumed implication of Pallas is historically anachronistic.]

Moreover, although his description of mountains and deserts between Russia and Tibet is relatively long, he had personally not seen them but accepted the account of travelers to China and Jesuit missionaries who worked there. He was very impressed by the high elevation of the deserts in central Asia which he deduced from the surrounding mountains that appeared higher and higher, as in steps, and from barometric measurements by Jesuit missionaries. As an outstanding botanist, he was also impressed by creeping bushes as proofs of high elevation. He believed that the plains in Central Asia resulted from the weathering of granite. With that idea he introduced an early concept of our present notion that mountains 'drown in their own weathering products.' Weathering products of granite represented for him the prerequisite for the formation of soil which favored the development of a specialized plant kingdom.

In his description of the Altai, he repeatedly stressed the close relationship between granitic mountains and the occurrence of certain mineral deposits. In Kamchatka, the Caucasus, and the mountains surrounding the Caspian sea, he pointed to the importance of recent volcanism."

Topic No. 2 [Schistose bands or primitive schists]: "According to Pallas' observations, granitic mountains are everywhere accompanied by a band of schists, that is, by rocks belonging to mountains of the first order. They are typically vertical or highly inclined, adjacent to granite, showing transitions between schists and granite. Large deposits of pyrites occur in schists which, in contact with combustible material, cause volcanism (see Stössner, 1900, p. 12). He believed that rocks of the schistose band had undergone secondary changes through high temperatures and, probably as one of the first naturalist, he formulated the concept of metamorphism [contact metamorphism]. The various rock-types in the schistose band show a directional succession. He believed that these rocks were very old, older than the creation of organized beings because they contained no fossils as did granites. However, he stressed that, in general, further observations and mining works were necessary."

Topic No. 3: [Limestone mountains of second order] "Limestone mountains are adjacent to the schistose band. They consist of two types which can be distinguished on the basis of their origin, their nature, and their degree of deformation. [Pallas said that these rocks differ in regard to their elevation, the position of their beds, and their composition, p. 49.] This difference is particularly striking on the west side of the Ural, that is in the 'Ural-Vorsenke' [foredeep]. He gave a very accurate description of the geologic difference between the western and eastern side of the Urals (East-European and West-Siberian plate).

Type 1: Immediately adjacent to the band of schists are deformed and hence very inclined *chemogene* [deposited by chemical processes] series of limestone. He stressed that the strike direction of limestones and the direction of schists, 'schistosity', coincide. Pallas thus presented an early concept of the phenomenon of schistosity and of late geological processes. He described in detail caves with stalactites in calcareous rocks which were thus formed either by karstic or by tectonic processes. [Less modern, Pallas mentioned disruption of beds and underground springs which softened, eroded, and transported soluble parts of limestones.]

Type 2: Following the first type of limestones are almost horizontal layers of fossiliferous limestones of the second type, overlying beds of clay. They were caused either during a sudden huge flood or by deposition in a calm and deep sea. [Pallas stressed that fossiliferous limestone beds were formed on the bottom of a calm sea during a long period of time (p. 53, 55) whereas disruption of limestone beds were caused by the running off of the waters toward the pole (p. 54-55).] Pallas thus described the differentiation of sediments in a particular environment, their distinction into lithofacies of chemical and biogenic limestones and also of clastics. He mentioned the relative age of these rocks as representing 'a long period of centuries.'

The clay layer underneath limestone consists of coal-like shales and large masses of pyrites, namely iron-sulfides which result from the reduction of organic substances. This pyrite lit the coal-like shales and caused volcanic activity.

The huge plains west of the Urals, that we call the old East-European plate, were, according to Pallas, covered by an ancient ocean. Typically, he extended this occurrence with great enthusiasm to the role of Russia as the 'seedbed' for heroes, as the last refuge of sciences and art as well as a great example for other countries. Finally, he wondered about the causes of the disappearance of the ocean and the formation of mountains concluding: 'I believe that one should combine the general effects, observed in all the countries of the Earth, of volcanoes, and other underground forces, with those of one or several huge floods or overflows of the ocean to give plausible reasons for all the changes which undoubtedly have occurred on our globe.''

Topic No. 4: [Flötzgebürge or mountains of third order]. ''The series of limestones were covered by *Flötzgebürge* or mountains of third order consisting of sandstones, reddish marls, and clays which spread out west of the Urals, and also of *Sandschiefern* [arenaceous shales] with copper-ores as for instance in the Government of Orenburg. He mentioned also the occurrence of gypsum which points, according to him, to the presence of underground salt springs, namely salt and saline deposits. These rocks contain relatively few fossils; instead they contain great amounts of petrified plants, trees, and remains of land animals. The most important characteristic of these *Flötzgebürge* are remains of animals from India: he mentioned elephants, buffaloes, rhinoceros, etc.

Thus Pallas concluded the description and analysis of geographical and geological phenomena observed during his academic expedition through a large part of the Russian empire.

Following this analysis, he gave the synthesis in the form of a hypothesis which explains the present state of the surface of our Earth. This hypothesis repeats first in a concise way the main topics of his analysis and includes thereafter the dynamic aspect of geologic processes.

Granitic mountains were always islands above the level of the sea. The products of the decomposition of granite formed sandstones and schists of the 'old' mountain. [Pallas said quartzose and feldspathic sand and micaceous clays which are the ingredients of the sandstone- and schist-bands in the old chain.] The ocean, whose bottom consisted also of granite, was inhabited by organic substances (remains of animals and plants) from which the pyrite layer and hence volcanism originated (by the lightning of organic substances) as the main cause of mountain-building. Volcanic activity caused jolting and deformation of already hardened material (*Diagenese*) into which *Vulcanites* [volcanic material] were injected, melting the adjacent rocks. Thus were formed most rocks of the band of schists which somehow — he does not say how — are connected with the other rocks. [Wendland seems to have misunderstood Pallas' implication of contact metamorphism involving not only a change from shales to schists, but also from limestones to marbles. He mentioned Pallas' metamorphism only with respect to rocks of the schistose band (p. 77).]

Pallas believed that volcanism was the main cause for the uplift of the 'European Calcareous Alps.' Further proofs of volcanism were, according to Pallas, its occurrence in space and time, and its continuation until today, as well as submarine volcanism which caused the appearance of new island arcs in the ocean.

Pallas then explained in detail how oceans became lands after deposition of calcareous rocks and clays and how solid land was weathered and eroded, so that coastlines changed. The main reasons of these changes are endogenous: huge earthquakes, large submarine fires which opened the seafloor, the lifting of masses of water that caused an enormous flood. At the same time, immense abysses opened in the interior of the Earth, as well as huge caves and fissures, which gradually led to the diminution of the sea and to its present level. He searched for other natural explanations to explain the development of such floods and found them in recent history, for instance: hurricanes, tidal waves, the resistance of straits that increase the power of the flood, tsunamis as a result of earthquakes, and in particular volcanism.

Pallas adopted Jussieu's thesis that such floods originated in the 'south or the Indian Ocean.' The major arguments that a sudden catastrophic flood had occurred were based on the many remains of land animals in the northern lands, animals that usually live in the tropics. This means that Pallas did not understand that remains of plants and animals were native of Siberia and that paleogeographic conditions had changed. He related volcanism, the eruption of a seafloor on fire, to the formation of island arcs in modern oceans. Such eruptions had to chase enormous masses of water. This catastrophic flood occurred from south to north, where it caused great destruction and deposited the load of rocks it carried along. These deposits represent the mountains of third order. The water of the ocean ran off and filled many cavities on land thus producing lakes and large bays in the northern seas. The latter, he said, are the result of the irruption of floods of the seas as well as the diminution of the sea.

Pallas compared this huge catastrophy which occurred once or several times with the Mosaic flood of the Old Testament and referred in that regard to the ancient civilizations of Asia.

Pallas terminates his theory with important scientific arguments, declaring that his hypothesis is not without error but that any incompassing geologic theory had to rest on more than one cause."

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CHAPTER VI

MODERN GEOLOGY OF THE URAL MOUNTAINS

INTRODUCTION

The Urals belong to the Hercynian orogenic system and began as a rift system between the Fenno-Sarmatien shield in the West and the Tobolsk shield in the East. The north-south trend of the chain is bent around the Ufa Plateau.

A synthesis based on numerous works (Garan, Gorsky, Koptev-Dvornikov, Kuznetsov, 1937, Aladanskii and Sobolev, 1956) shows that the Urals consist from west to east of several major structural units which are as follows. A foreland represented by the Permian Ufa Plateau; a western slope consisting of westward thrusted sedimentary rocks of a foredeep basin; a Precambrian geanticlinal wedge (Ural-Tau) almost in vertical position, forming the highest crest of the range and the watershed line; a zone of basic and ultrabasic and mineralized intrusives immediately adjacent on the east to the geanticline; and a highly folded and complex zone of metamorphics of green schist facies associated with radiolarian cherts, jaspers, and abundant ophiolites, andesites, and basalts. This zone represents the main trough of the Urals characterized by extensive and long-lasting submarine and island-arc volcanism. Granitic batholiths of Hercynian age intruded this metamorphic zone in many places, but tend to form a major and more continuous belt along its eastern margin. The easternmost margin of the chain, particularly in the southern Urals, consists of a tightly faulted and intruded metamorphic-sedimentary belt, thrusted eastward and eventually covered by Jurassic to Cenozoic clastics. These in turn are overlain by Pleistocene glacio-fluvial gravels and sands of the Siberian Plains.

Morphologically, the highest points and the watershed line of the Urals are located along the Precambrian metamorphic zone which resisted best to denudation. The elevation is 1600 to 2000 m in the north, 600 m in the central Urals, and 1000 m in the south. The western slope is really an uplifted plateau, 500 to 600 m high, dissected by streams into flat hills. The eastern slope is a gently sloping surface with numerous ridges corresponding to basic intrusions and granitic batholiths. Its average elevation is 150 to 200 m.

Bubnoff (1926, 1952) divided the Urals into 6 major longitudinal zones separated from each other by major thrusts (Fig. 2). This division has been generally accepted (Saforov, 1937; Termier and Termier, 1956) and is described below in more detail from west to east.

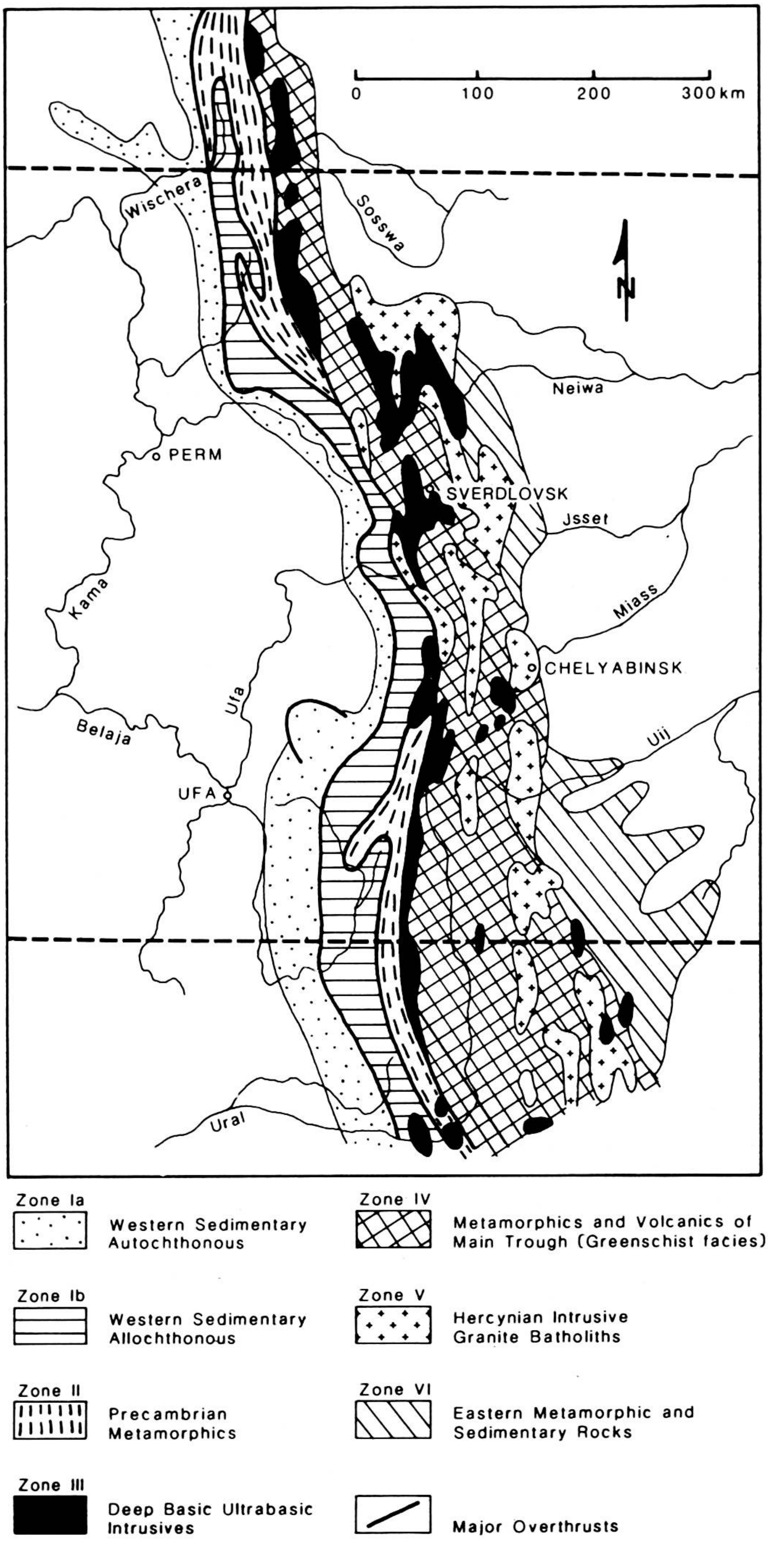

FIG. 2.

Structural map of the central Urals and their bend against the Ufa foreland. Modified from Bubnoff (1952). Dashed E-W lines indicate the boundaries of Pallas' geological map (1773).

Zone Ia. Western sedimentary autochthonous

It consists of flat beds becoming increasingly folded toward the east until the overthrust plane of the next zone Ib. The sequence consists of complete Carboniferous with Tournaisian limestones grading upward into sandstones, shales, and coal beds; widespread and fossiliferous Viséan limestones with *Productus* and the coral *Dibunophyllum;* Namurian-Moscovian limestones with *Choristites mosquensis.* The overlying Permian is as follows: Artinskian conglomerates, sandstones, shales, and arenaceous limestones; Kungurian dolomites, limestones, gypsum, evaporites, sandstones, and shales; Kazanian sandstones, conglomerates, and marls.

Zone Ib. Western sedimentary allochthonous

This zone consists of a highly folded sequence in numerous isoclinal structures between westward oriented thrusts which terminates eastward by a complex fan-shaped structure against the Precambrian geanticlinal wedge of the next zone III. The sequence of zone Ib ranges from Cambrian to Carboniferous, with Cambrian-Ordovician in the fan-shaped structure adjacent to the geanticline, followed westward by Silurian beds, then by large overthrusts with Carboniferous coal beds in overturned synclinal position with underlying Devonian. The sequence is as follows. The Cambrian consists of alternating phyllites, quartzites with unfossiliferous to poorly fossiliferous limestones and dolomites with *Archaeocyathus.* The Ordovician shows bituminous shales with graptolites and a first volcanic episode of gabbros and diabases. The angular unconformity of Mugojary between Ordovician and Silurian represents the Taconic orogeny. The Silurian consists of gray to yellow limestones and dolomites with rare fauna of brachiopods, ostracods, and corals. The Devonian is an association of sandstones, shales, rare limestones, and bituminous shales with Goniatites. The Carboniferous is similar to that of zone Ia with abundant coal beds and widespread limestones with *Productus.*

Zone II. Precambrian (Proterozoic) metamorphics

This central geanticline, not recognizable in the central Urals, is limited on both sides by high-angle thrusts dipping in opposite directions. Between them, are numerous isoclinal folds with high development of schistosity. The metamorphics of epizone to mesozone type are micaschists, quartzites, feldspathic quartzites, and rare gneisses associated with abundant amphibolites representing metamorphosed porphyrites, gabbros, and gabbro-diorites. In the region of Bakal-Satka-Kusal, the Proterozoic is overlain unconformably by a very thick sequence of Eocambrian molasse-type clastics with a few limestones with *Archaeocyathus.*

ZONE III. DEEP BASIC TO ULTRABASIC INTRUSIVES

This zone consisting of diorites, gabbros, peridotites, and often serpentinized dunites still shows an eastward dipping attitude. It is continuous in the northern and southern Urals, but divided into isolated patches in the middle Urals where it may occur on both sides of the Precambrian ridge. It is the equivalent of a serpentine belt.

ZONE IV. METAMORPHICS AND VOLCANICS OF THE MAIN TROUGH

The metamorphic rocks of this zone belong to the greenschist facies. They are associated with abundant ophiolites, andesites and basalts, graywackes, radiolarites, and red jasper. They have been folded in a complex manner but erosion has destroyed most of the structures leaving only vertical and eastward thrusted sequences separated by scattered basic intrusions and Hercynian granitic batholiths. The sequence of this zone is as follows. Upper Silurian: porphyrites, diabases of Nijni-Tagil, green schists. Lower Devonian: porphyrites, diabases, red jasper, and marbles. Middle Devonian: abundant red jasper, albitophyres, tuffs, green schists, rare limestones with *Pentamerus*. Upper Devonian: green graywackes, radiolarites, diabases. Lower and Middle Carboniferous: porphyritic basalts, quartz porphyries and tuffs which represent the last products of this volcanized and highly metalliferous belt. The repeated association of graywackes — schists — variegated radiolarites (jasper) — ophiolites indicates a typical subduction zone.

ZONE V. HERCYNIAN INTRUSIVE GRANITIC BATHOLITHS

Although intrusive granites occur scattered within zone IV, most of them form a more continuous zone along its eastern margin which can be considered an entity in itself. Numerous types occur which are very pneumatolitic, including rapakiwi granites. They were intruded during late Carboniferous, between Bashkirian and Moscovian, taking advantage of the location of ultrabasic intrusions within the green schists of the main trough.

ZONE VI. EASTERN METAMORPHIC AND SEDIMENTARY ROCKS

This tight isoclinally folded, faulted, and eastward thrusted belt is similar in some aspects to zone IV of the main trough, but is at the same time one of the most characteristic zones of the Urals. The sequence is as follows. Silurian: green schists, diabases, and porphyries. Devonian: porphyrites, diabases, graywackes and limestones. Lower Carboniferous: sandstones, shales, coal beds, and Viséan limestones with *Productus giganteus* and *P. striatus,* porphyritic basalts, quartz porphyries, diabases, and tuffs. Middle-Upper Carboniferous: sandstones, conglomerates, rare limestones with *Choristites mosquensis* (Moscovian). The Carboniferous is distinguished by many emergences, volcanic activity, and displays more coal beds than on the western flank of the Urals. Typically of this zone, most of the diabases, diorites, and porphyries were intruded as large vein-like bodies along the fractures of a phase of brittle deformation following the main orogeny, and not before as in zone IV. Consequently, metamorphism is well developed but of variable intensity, and many coal beds are locally changed into anthracite or graphitic schists. The rocks of the Eastern Flank disappear under the Mesozoic-Cenozoic sediments of the Siberian plains.

Post-Tectonic evolution

The major episode of folding and thrusting in opposite directions took place at the limit Ouralian-Artinskian, and was preceded by granitic intrusions. During late Triassic, the chain underwent a period of intense erosion which eventually unroofed the granitic batholiths intruded in the green schists. Continental beds of the Lower Jurassic where then deposited over peneplained surfaces as extensive sands, clays, bauxites, oolitic iron ores, and brown coal. A marine transgression from the east began in the Cretaceous and may have reached the Precambrian axis. It culminated with the Upper Cretaceous with phosphatic glauconitic sandstones and continued during the Lower Cenozoic before ending in continental beds. The Pleistocene consists of lacustrine peat, outwash gravels and sands with bones of mammoth in the Siberian plains under the influence of glacial deposits in the Northern Urals, and of Recent deposits of gold and platinum placers.

Tectonic comparison of the Urals with the Alps

Bubnoff (1952) compared the structure of the Urals (Fig. 3) with that of the Alps as follows. Zones Ia, Ib, and II represent the Helvetic nappes of the Alps with their associated Hercynian massifs and wedges. Zones III and IV are equivalent to the Pennine metamorphic nappes, whereas zones V and VI would correspond to the Austro-Alpine overthursts. However, in the Alps the important N-S compression has thrusted the various structural units on top of each other in a northward direction, whereas in the Urals, the weak E-W compression has been unable to have such an effect so that the various structural zones are still next to each other in their original position. They are only involved in a general fan-shaped system which consists of thrusts of appreciable amplitude, but in no way comparable to Alpine nappes.

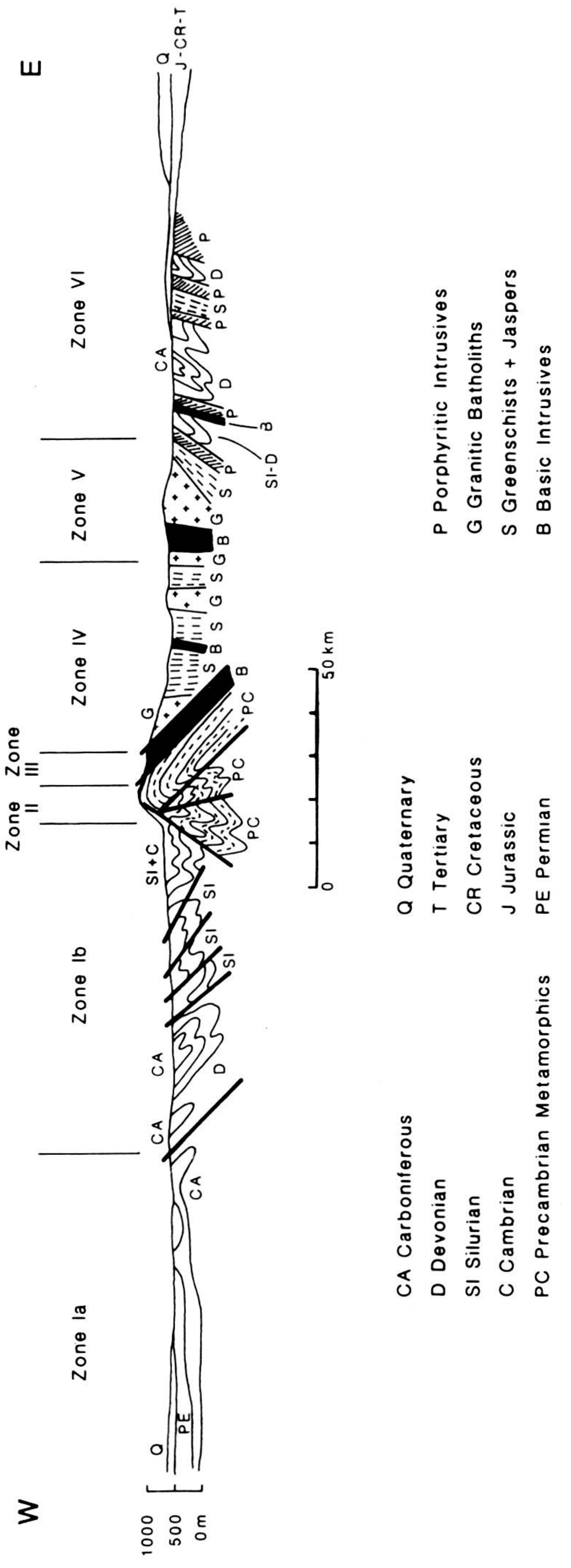

FIG. 3.

Schematic E-W geological cross-section of the southern Urals with the structural zones of Bubnoff (see Fig. 2). Modified from Garan, Gorsky, Koptev-Dvornikov, and Kuznetsov (1927).

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CHAPTER VII

PALLAS' GEOLOGICAL MAP OF THE URAL MOUNTAINS (1773)

Pallas' map entitled "Karte des Uralischen Berg und Hüten-Reviers vom Ursprung der Bjelaja bis an die Soswa" was published as an illustration in Part II, Book I, p. 368 of his *Reise durch verschiedene Provinzen...* (1771-1776).

Its scale is approximately 1: 1,400,000. The origin of its topographic background is not given. The map is plagued by numerous distortions and has neither grid nor latitudes and longitudes. It emphasizes streams as well as lakes and marshes which are both the arteries of penetration of this difficult and covered terrane and its pitfalls. Location names are strongly emphasized toward mining sites. All mountains, without barometric elevation, are systematically represented by the symbol of a conical hill, and only along the watershed line do these symbols carry a cross on top.

On this rather rudimentary background, Pallas superposed the results of his field observations with a combination of punctual symbols used at his time which may be designated as "mineralogical" and "structural" (See F. Ellenberger, 1985 for an exhaustive discussion of the subject). The first group of seven symbols used by Pallas represents the major rock-types in part defined by their structural attitude. The second group of fifteen symbols are of economical interest including particular rock-types, minerals, metallic ores, mineralized springs combined with written designations on the map, such as marble, magnetite mountain, asbest mountain, and burning mountain (burning seeps of natural gas).

The first group of punctual symbols represents Pallas' primitive, secondary, and tertiary mountains (named mountains of first, second, and third order by Pallas) which form distinct bands (*Strich*) although the boundaries between the bands are not marked on the map by solid lines. As mentioned in Chapter II, Pallas' symbol for *Schiefer Ganggebürge* pertains both to shales and schists, namely highly inclined to vertical shales on the west side, including some schists, and metamorphic schists on the east side. This symbol has a variable orientation on the map to indicate the approximate observed dip of the schistosity at a given location.

The symbols of the first group (Fig. 4) are designated as follows:

Vitrescirendes Gebürge u. Quarz.: vitreous rocks (metamorphics, quartzites, and quartz veins). Primitive mountains.

Schiefer-Ganggebürge: highly inclined to vertical shales and some schists (west side) and metamorphic schists (east side). Primitive mountains.

Kalk Gebürge: inclined to folded limestone beds. Secondary mountains.

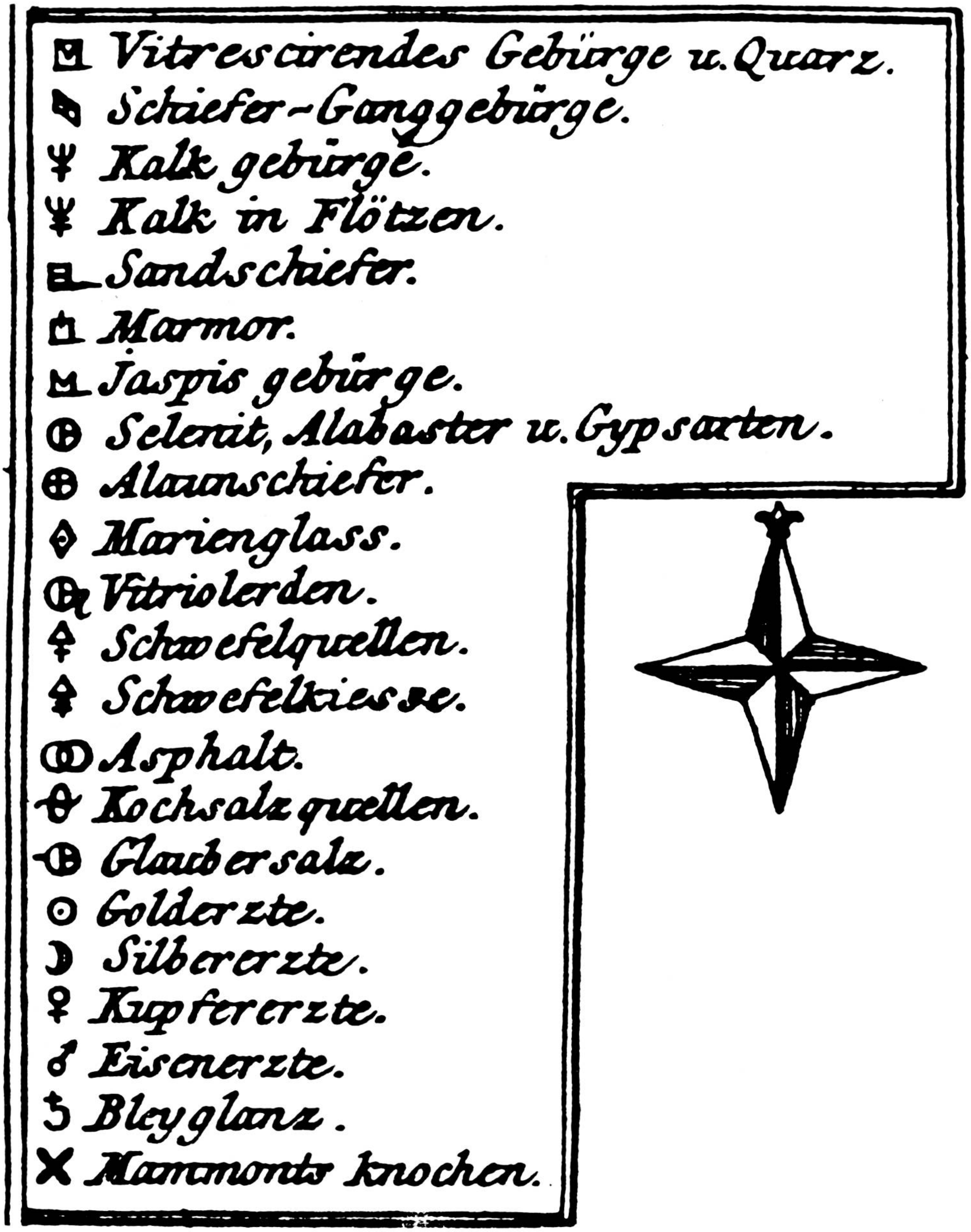

FIG. 4.

Legend of punctual symbols of Pallas' geological map (1773).

Kalk in Flötzen: horizontal limestone beds. Secondary mountains.

Sandschiefer: alternations of sandstones, shales, and marls. Tertiary mountains.

Marmor: marbles intercalated in the metamorphic schists of the east side. Primitive mountains.

Jaspis Gebürge: jasper (radiolarites) intercalated in the metamorphic schists of the east side. Primitive mountains.

The symbols of the second group (Fig. 4) deal essentially with materials of economic interest and are as follows:

Selenit, Alabaster u. Gypsarten: selenite, alabaster, and various forms of gypsum.

Alaunschiefer: alunite shales or schists; alunite or alumnstone. $KAl_3(OH)_6(SO_4)_2$, basic potassium aluminum sulfate, used in medicine as astringent, in dyeing, in tanning, and many other industrial uses.

Marienglass: selenite or transparent gypsum in large platy crystals found in veins from which are extracted large slabs used for windows. The term *Marienglass* (also called *Fraueneiss* or *Frauenglass*) is a symbol for purity of the Virgin Mary.

Vitriolerden: any kind of sulfate-bearing shales, probably copper sulfates.

Schwefelquellen: sulfurous water springs.

Asphalt: natural seeps of oxidized petroleum (tar pits).

Kochsalzquellen: salt water springs.

Glaubersalz: Glauber's salt (sodium sulfate).

Golderzte: gold ore.

Silbererzte: silver ore.

Kupfererzte: copper ore.

Eisenerzte: iron ore.

Bleyglanz: galena, lead ore.

Mammonts Knochen: Pleistocene mammoth bones.

For a comparison between Pallas' map and modern knowledge and to evaluate his understanding of the geology of the Urals, we have traced on his map, as accurately as possible, the boundaries between areas of similar punctual symbols of the major rock-types, thus changing his map into one with bands (Figs 5, 6, 7, zones A-I).

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FIG. 5.

Partial reproduction of Pallas' geological map of the central Urals (1773) with punctual symbols, showing the bend against the Ufa foreland.

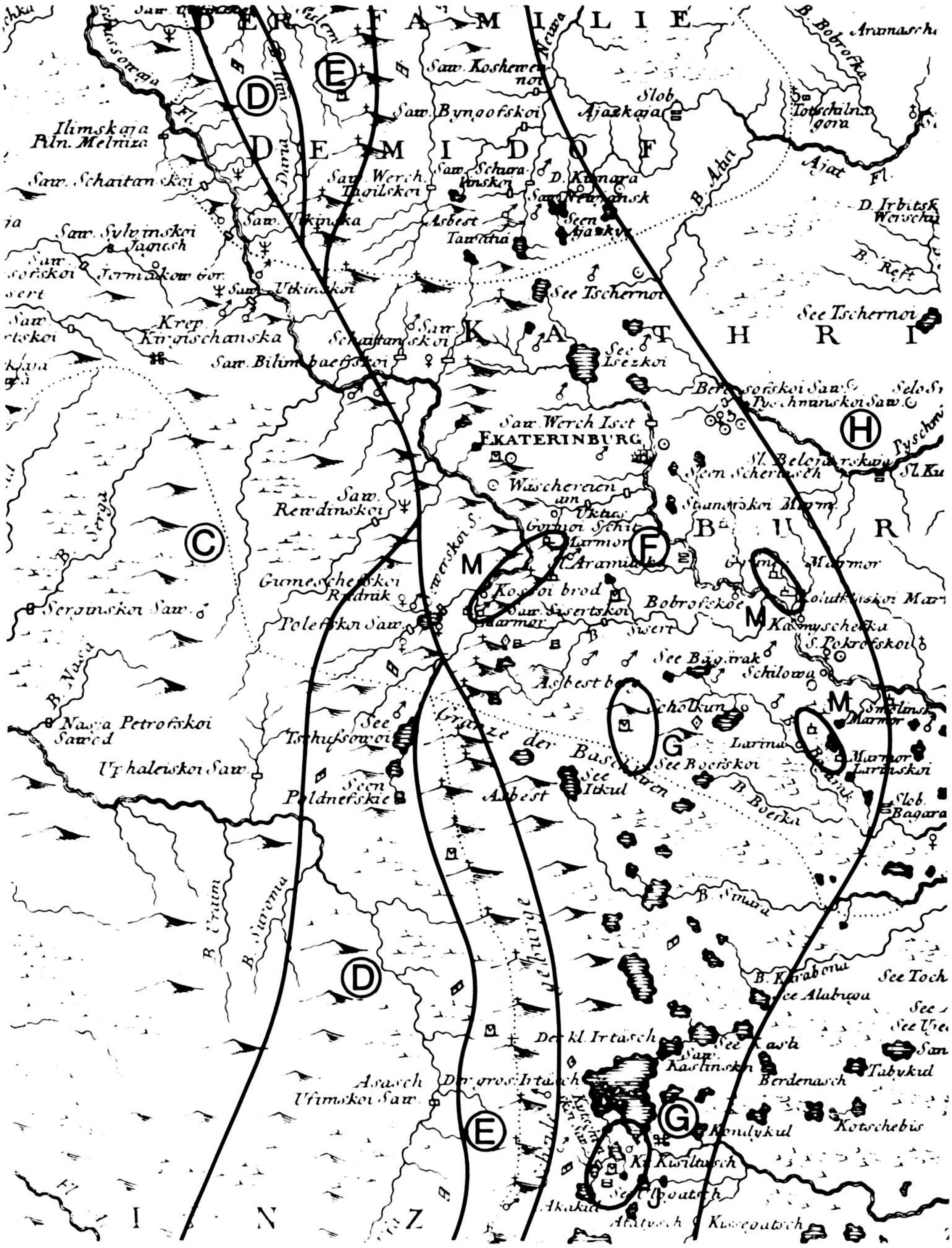

FIG. 6.

Example of transformation of the portion of Pallas' geological map with punctual symbols of Fig. 5 into a map with bands. For the meaning of the letter symbols, see legend of Fig. 7.

CHAPTER VIII

PALLAS' JUSTIFICATION OF HIS FIELD UNITS — COMPARISON WITH THE MODERN GEOLOGY OF THE URALS

In 1768, Pallas left St. Petersburg in charge of one of the five expeditions planned by the Academy of Sciences. He first described deposits of sands, marls, clays, and some large boulders, and wondered how the latter had been transported. Near Moscow, he found a soil rich in marine bodies [*Reise...* (1771-1776) Part I, p. 6-14] and at Lawisinka, in the country of the Tatars, he saw lots of fossils between layers of limestones and pebbles rounded by the sea and wrote that the common corals of an ancient sea floor were *Madrepora fastigiata* [p. 26]; further down the Volga, he saw asphalt springs and bituminous vapors; sulfur springs and limestones consisting of empty shells of snails [p. 101-109]. He spent his first winter at Simbirsk on the Volga [today Ulyanovsk] on the banks of which the remains of elephants [mammoths] were found. He wondered how these bones had been preserved for so many years and suggested that these and other animal remains scattered far toward the North Sea were the traces of a great catastrophe which had happened on the surface of the Earth [p. 140-141].

He left Simbirsk on March 10, 1769, and traveling along the Volga river, he described a chain of limestone mountains with bare cliffs and many cuts, about 100 feet high [p. 141-143] and at Samara [today Kuibyshev] a section on a river bank from top to bottom: black soil, chalky marl, gypsum, agates [p. 151]. Near Syzran he described coal measures of poor quality and underneath them heaps of belemnites and other marine fossils; and in the region of the Ussa River large masses of ferruginous clay, and salt springs [p. 173-178]. At Orenburg, he visited salt and copper mines in yellow, coarse *Sandschiefer* with pockets of copper. Near most copper mines south of the Urals and along the Ural river, he noticed petrified wood under black soil and wondered why these woods occurred so frequently there whereas they were rare elsewhere [p. 247-248]. So far Pallas understood that many deposits were traces of the sea, as for instance the fossiliferous limestones that had been deposited in a calm sea. He believed that large boulders, elephant bones, and petrified wood pointed to some previous catastrophe that was capable to transport all these materials.

Only after his second winter, at Ufa, did he cross the Ural Mountains and hence Part II, Book I, including his map, contain observations from the Urals between the rivers Belaya in the south and Soswa in the north. His geological map, which we have reconstructed from a representation by symbols to one by bands, and divided into nine zones (Fig. 7, zones A-I], is thus based essentially on the central part of the Ural Mountains.

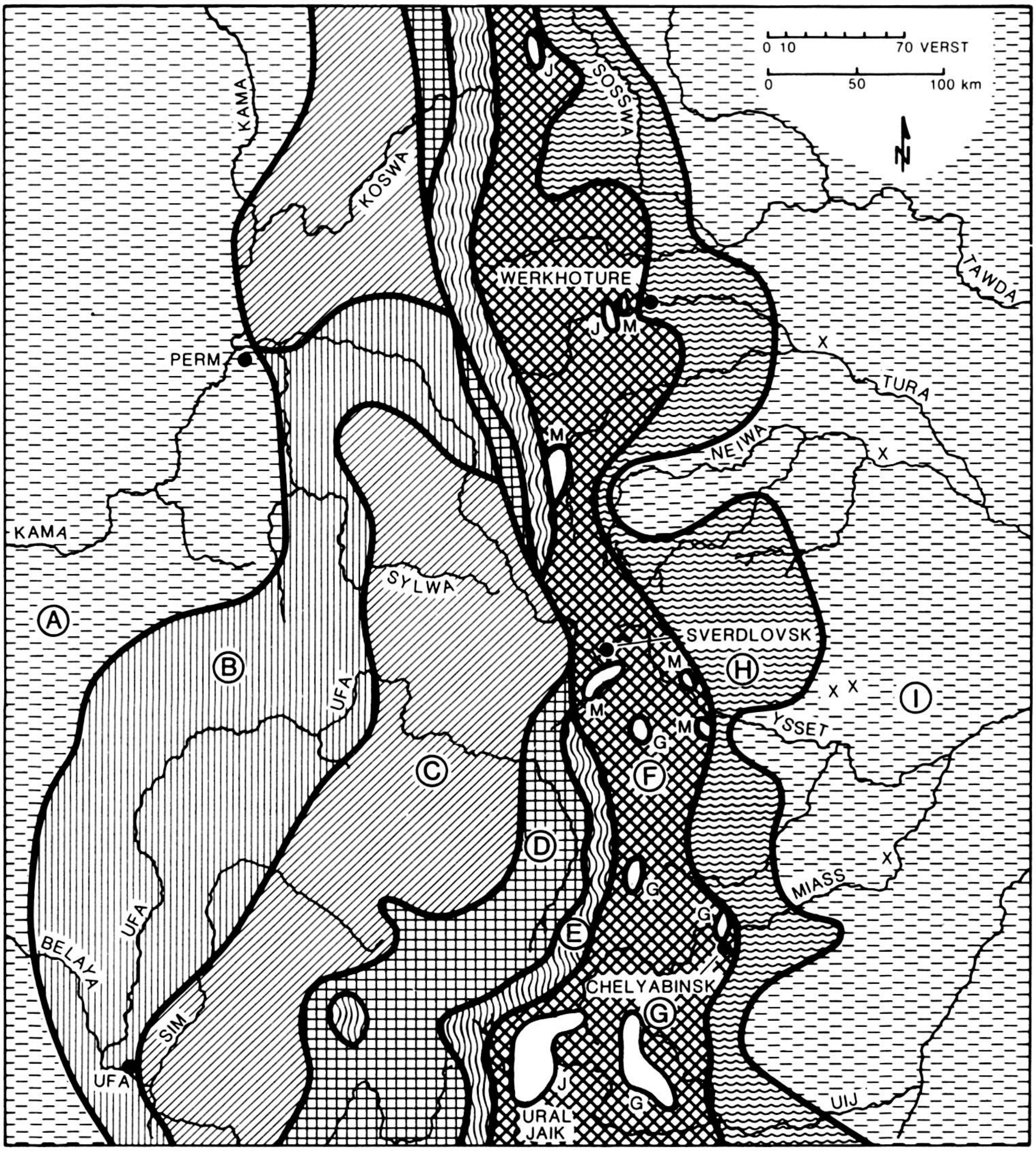

FIG. 7.

Pallas' geological map (1773) interpreted by bands.

Western Flank of the Urals

A. *Sandschiefer:* mountains of third order.

B. *Kalk in Flötzen:* horizontal limestone mountains of second order.

C. *Kalkgebürge:* highly inclined to vertical limestone mountains of second order.

D. *Schiefer-Ganggebürge:* inclined to vertical primitive schists (shales).

Axial Zone of the Urals

E. *Uralische Felsarten-Vitrescirendes Gebürge und Quartz:* "granite" (in fact metamorphic feldspathic quartzites).

Eastern Flank of the Urals

F. *Schiefer-Ganggebürge:* vertical primitive schists (metamorphic schists with bodies of marbles (M), jasper or radiolarites (J), and serpentine.

G. *Porphyr Granitfelsen:* porphyritic granites (G) belonging to Hercynian batholiths intrusive in metamorphic schists of zone F.

H. *Kalkgebürge:* poorly developed vertical to highly tilted limestone mountains of second order among many other types of metamorphic and sedimentary rocks.

I. *Sandschiefer:* mountains of third order with mammoth occurrences (x).

Below are Pallas' observations according to his written text and his symbols — some symbols drawn on the map are not described in the text — followed by a comparison modern structural units.

Zone A: Pallas' zone of *Sandschiefer,* partly recorded in his notes written between St. Petersburg and Ufa — briefly mentioned above — corresponds to post-tectonic sediments on the west side of the Ural Mountains, but in the domain of his map it is only Pleistocene outwash gravels with mammoth bones, resting on Permian limestone.

Zone B: On the banks of the Belaya and the Ufa, Pallas noticed hills of *Kalkschiefer* [called *Kalk in Flötzen* in his map] or gypsum, as well as calcareous marl and potter's clay [Part II, Book I, p. 9] *. In modern terms, these are fossiliferous limestones and shales in horizontal beds. This zone corresponds to the Western Sedimentary Autochthonous zone [Fig. 2, *Zone Ia*], that is, mostly limestones, dolomites, gypsum, sandstones, shales, and marls, belonging to the Carboniferous to Permian of the Ufa plateau.

In the middle and upper part of the Ural chain, zone B is immediately adjacent to Pallas' *Schiefer Ganggebürge,* that is, zone D west of the Ural.

Zone C: Near Symskoi Sawod, Pallas found limestone mountains in vertical position, yellow or gray, very hard, and mostly without fossils [p. 28] for which he used the symbol of *Kalkgebürge.* These are fossiliferous limestones with rare fossils in highly inclined [folded and thrusted] to vertical beds. Zone C corresponds to the western part of *Zone Ib* [Fig. 2], a complexly folded sequence of Silurian-Devonian to Carboniferous limestones, dolomites, shales, etc.

Zone D: On the banks of the Katau river and at Jurjusenskoi Sawod, Pallas observed hard, coarse, and gray *Kalkschiefer* or *Kalkberge* in vertical position [p. 35], and at Orlofka, various rocks consisting of soft, brown-greenish and grayish *Schiefer* [shales, p. 37]. On the burning mountain (*Brennender Berg*] he found reddish *Fliesenstein* [flagstones], burnt and ringing but calcareous, with thin layers of schistose rocks. He said that on the east side of the mountain, rocks consist of coarse slates, but the further down, the finer and looser they are [p. 54-56]. All the above rocks that Pallas labeled as *Schiefer-Ganggebürge,* correspond to the eastern part of *Zone Ib.* [Fig. 2]. They consist on the west side of the chain of weakly metamorphic to nonmetamorphic rocks, Cambrian shales, phyllites, and quartzites, Ordovician bituminous shales, etc. The reddish flagstones are shales changed into slates by heating of burning natural gas seeps.

At Troizkoi Satkinskoi Sawod, Pallas found gray marble-like limestones with feldspar veins [p. 70] which correspond also to the above-mentioned *Zone Ib*, perhaps of Cambrian age.

* All pagination hereafter, if not mentioned otherwise, refers to Part II, Book I.

Zone E: Above the springs of the rivers Belaya, Ufa, Ai, and Miass, Pallas described the Ural-Tau [*Gürtelgebirge*] where the common rocks are a gray, reddish or whitish feldspar, or some quartzose rocks, either vertical or highly inclined toward the east [p. 72]. Further on he called these rocks the *uralische Felsart* [p. 73], namely rocks most characteristic of the Ural Mountains. This is the watershed represented on Pallas' map by the symbol for *Vitrescirendes Gebürge und Quarz.* It is significant that Pallas did not use the word granite for these rocks. In fact, these are not granites in the modern sense because the axis of the chain consists mostly of Precambrian rocks [Fig. 2, *Zone II*] namely metamorphics, micaschists, and feldspathic quartzites [See Chapter II on the eighteenth-century terminology of granite].

Zone F: Having crossed the watershed of the Urals, where the high cliffs of mountains gradually flatten out and become increasingly low toward the east, he observed vertical layers of outcrops consisting either of quartz, *Hornstein,* and many other rocks [p. 78]. In a rare cross-section of the various rocks he had seen when crossing the Urals, Pallas mentioned from west to east:

1. Hard limestone cliffs without fossils [west].
2. Various kinds of *Schiefer* and sandstones [west].
3. An iron-rich band of minerals formed at depth.
4. The hard *Quartz-und Feldspathgänge* of the Urals [center].
5. *Hornschiefer,* jasper of all sorts, micaceous schists [*glimmerige Schiefer*] and clays, rich in ores [east].

That night he crossed the river Miass and arrived late at Kundrawy [p. 79].

The above units 1-3 correspond to *Zone Ib* [Fig. 2] and Fig. 7 zone B; unit 4 consists of rocks typical of the Ural mountains, quartzite and feldspars, *Zone II* [Fig. 2] and Fig. 7 zone E.

Unit 5 corresponds to *Zones III and IV* [Fig. 2] namely Pallas' *Schiefer Ganggebürge.* This is zone F [Fig. 7] on the east side of the Ural, consisting of deep ultrabasic intrusives and metamorphic-volcanics of the main trough [greenschist facies]. As mentioned above, Pallas recognized micaschists with muscovite and biotite, abundant mineralization, jaspers forming isolated masses.

Further east he found garnet-schists, muscovite and micaschists, *Hornstein,* marbles, and quartz veins. For instance, Pallas noticed near Kundrawy, micaceous rocks, brittle schists, purple-brown irregular garnets [p. 80] which correspond to *Zone IV* [Fig. 2] and the same zone F [Fig. 7]; at Kosoturskoi, *Marienglass* [selenite or transparent gypsum in large platy crystals used for windows] and micaceous rocks [p. 85]; along the river Ai, in the Ueirtisch-Tau, alaun-schists [alunite-bearing schists] and *Steinbutter* (*Kamennose Maslo*) [also called *Bergbutter,* mountain butter is impure goslarite, $ZnSO_4 \cdot 7H_2O$, forming white-yellowish crusts or efflorescences, p. 87-88]; at the Tschebarkulska river (near the fortress of Tschebarkulskaja), micaceous *Hornfelse, Marienglass* between green rocks [p. 94-95, 97]; along the river

Tschesnoska, quartzites [p. 106]; on the Asbestos mountain, wetstones, asbestos, serpentine [p. 141-142]; at Sisertskoi Sawod, *Hornstein,* chlorite schists and garnet schists [p. 143]; at Kossoibrod, micaschists, talc [p. 144]; marble close to Gumeschefskoi Rudnik [p. 147] and at Kossoibrod and Gornoistschit [p. 156-157].

When he arrived at Ekatherinburg [Sverdlovsk], he visited gold mines and said that some gold-bearing veins consist of quartz, others of white yellowish mica schists, or *Hornstein* [p. 159-173].

Pallas marked on the map — not mentioned in the text — between the southern shore of Lake Tschernoi and Sawod Nishno Tagilskoi 3 symbols for *Kalkgebürge* which correspond in fact to a large mass of Lower Devonian marbles and limestones trending N-E instead of N-S as the surrounding schists.

Traveling along the river Tura, by the villages Palkina, Wologina, Bessonowa, Wassiljefskoi Rudnik, he found marble, vertical schists, serpentine, jasper [p. 218-233], jasper also at Wagranskoi [p. 255-256]. Between Werchotur'ye and Wologina, he discovered on the banks of the Tura elephant bones, belemnites and glossopetra [from the Jurassic, Cretaceous, and Tertiary, p. 266]. At Troizkaja Krepost, *Hornschiefer,* green and black serpentine [p. 293]; at Stepnaja Krepost, flat, gray, coarse-grained *Marmorwacken,* [p. 306, that is marble in large masses]. At Okto Karajai, he saw hills consisting of gray sandstone-schists [p. 312-313, probably graywackes]; on the Kalterma-Baschn-Karagash-Tube, soapy *Hornschiefer,* magnetite, and serpentine [p. 315-316].

On his map, but not mentioned in his text, he marked one site of jasper and marble on the Tura river, 30 versts upstream of Werchotur'ye, and another site of jasper close to Sawod Strogonowa.

Zone G: Near Kundrawy, beyond the Miass river [p. 82], (east of the Urals' watershed), he recognized rocks of porphyry, namely bodies of porphyritic granites intruded and scattered within Hercynian batholiths [Fig. 7, zone F]. They correspond to *Zone V* [Fig. 2]. Pallas apparently did not recognize their large extent. On his map, but not in his text, he mentioned two other occurrences of porphyritic granites: one near Kisiltasch and the Ulogatsch lake, the other at Scholkun, south of the *Asbestberg.*

At last, he spelled out the word "granite" close to Cheljabynsk [p. 101], (again east of the central axis of the Urals), when he recognized on the ground which was quarried a *quartzigten mit Blend gemischten Granitfelsen* [a granite with quartz and blende]. These rocks are true granites, namely diorites and porphyries injected as large vein-like bodies.

Zone H: On the northern part of his map, west of the Soswa river, Pallas marked many sites of *Kalk Gebürge.* In the area of the Iset river and Pyschma river, he marked *Kalk Gebürge* and marbles. These are the Eastern Metamorphic and Sedimentary Rocks [Fig. 2, *Zone VI*], consisting of green schists, porphyrites, graywackes, limestones with and without fossils [Devonian and Carboniferous], in short a very complex zone of which Pallas merely noticed limestones.

Zone I: This zone is the equivalent of zone A on the west side of the Urals. Pallas mentioned *Sandschiefer* at Okto Karagai only [p. 312-313] but put several symbols elsewhere on his map. This zone includes all post-tectonic sediments of the eastern flank of the Ural Mountains, Jurassic, Cretaceous, Tertiary, and Pleistocene outwash gravels with abundant mammoth bones in the Siberian plain.

A comparison between the modern geology of the Urals [Figs 2 and 3] and Pallas' map [Fig. 7] shows that Pallas achieved a remarkable understanding of the geology of the area by establishing the following features: the bending of the chain against the Ufa foreland plateau; from west to east, the horizontal and then the vertical band of secondary limestones of the west side [zones B and C]; the discontinuous band of primitive shales and schists of the west side [zone D]; the equally discontinuous axial band of primitive vitreous and quartzitic rocks of the Ural-Tau [zone F]; the wide band of primitive metamorphic schists of the east side with its rich mineralization, intercalations of marbles, jaspers and serpentines, intrusions of granite [zones F and G]; the complex and poorly-known easternmost belt of sedimentary and metamorphic rocks [zone H], and finally the overlap, on both sides of the chain, of *Sandschiefer* with the famous localities of mammoth bones on the Siberian side [zones A and I]. In short, Pallas' map shows that contrary to his statement in his theory of mountain chains in general, the various bands of rocks in the Urals are asymmetrical and granite does not exist at the center of the chain.

CHAPTER IX

PALLAS' THEORY OF THE EARTH (1778)

PALLAS' SUMMARY OF HIS FIELD OBSERVATIONS

Pallas never returned to the Ural Mountains. After a winter at Cheljabynsk — his third winter — he sent one of his students, Sokolof, to visit the Urals some more [p. 371-373, Part II, Book II], but nothing new was discovered. Pallas then traveled to the east, from Omsk to Semipalatnaja and Krasnoyarsk where he spent his fourth winter in poor health. He mentioned granitic mountains several times in the vicinity of the Altai [Part II, Book II, p. 494, 517, 522, 587, 589] but made no further personal investigation.

In Part III, Book I, he described the remains of a rhinoceros (discovered by a hunter at the Viulyuy river [p. 97-98]), and his journey to Lake Baikal and the Mongolian frontiertown of Kyakhta. He spent his fifth winter in Krasnoyarsk and from there he went to the region around the Caspian sea saying it was cheaper, healthier, and more interesting for botany [Part III, Book II, p. 458]. He returned to St. Petersburg on July 3, 1774, "at the age of 33, with a tired body and some grayish hair, but," he said, "healthier than he had been in Siberia [Part III, Book II, p. 690].

In Part III, Book I, a foreword gives Pallas' summary of his field observations at the time. It is difficult to know the exact date when it was written, whether in Krasnoyarsk or later in St. Petersburg before Part III was printed. It is obvious that he had met or read some famous naturalist from Sweden since he said, "The Ural mountains show great similarities with those of Sweden and other European mountains which have become known by thorough investigations."

In this summary, Pallas stressed first, "In my maps [of Part II], I have never given a symbol if I did not know the place and its content well enough. For the same reason, I have indicated the types of mountains only when their relationship could be deduced with great probability."

He then gave a description of the various rock units of the Urals which forecasts his theory written a year later. He reported the fundamental difference between western shales and eastern schists, as well as the overwhelming presence of limestones in the west compared to the east side, hence a lack of symmetry. He wrote that the axial zone of the Urals consisted, as in other major mountains on Earth, of granite and other vitreous rocks, though his field notes said otherwise. This comparison was omitted in the theory. It became of genetic significance, that is a theory of the Earth, when he introduced uplifting, folding, and metamorphic actions of various episodes of volcanism, and of course the gigantic flood from the Indian Ocean.

NEW INTERPRETATION OF PALLAS' THEORY OF 1778

Pallas' theory can be summarized by means of seven schematic stages (Figs 8-10) which represent a generalized E-W cross-section of the Urals, not to scale.

Stage 1 (Fig. 8)

The original granitic island is exposed to weathering and fluvial erosion. Both processes generate quartzose and feldspathic sands as well as micaceous clays deposited as subaerial to subaqueous talus. These sediments are more sandy on the west side and more argillaceous on the east side. This difference in composition of the clastic yield continues throughout the history of the Urals in various forms, contributing to the asymmetric nature of the chain. The micaceous clays extend farther on the ocean floor than the coarser sands, both sediments are the constituents of the primitive schistose bands. At this stage, the ocean is devoid of organisms.

Stage 2 (Fig. 8)

The ocean contains combustible organic matter and iron generated by the decay of marine plants and animals. These materials are floated toward the coasts where they infiltrate downwards into the quartzose and feldspathic sands and micaceous clays and generate concentrations of pyrite, the fuel of volcanoes. These concentrations correspond, on both sides of the chain, to the first centers of volcanic activity.

Stage 3 (Fig. 9)

During this first stage of active volcanism, lavas (basic rocks) intrude upwards and uplift the quartzose and feldspathic sands and the micaceous clays. Fires dislocate and tilt rocks into a vertical position while they are also partially melted and injected with mineral veins, both as individual bodies and as stockworks. Contact metamorphism, undergone by sands and clays, is relatively weak on the western side where they are changed into sandstones and shales. It is more powerful on the eastern side where mineralization is very intense (major mining districts of the Urals) and various types of metamorphic schists are generated (greenschist facies) associated with abundant masses of quartz, marbles, and jasper.

The schistose band of the west grades further westward into unchanged sandstones and clays which are subsequently exposed in deep river cuts beneath younger deposits.

Stage 4 (Fig. 9)

This phase corresponds at first to further erosion of the granitic axial zone, and particularly to a complete destruction of the morphological expression of the first

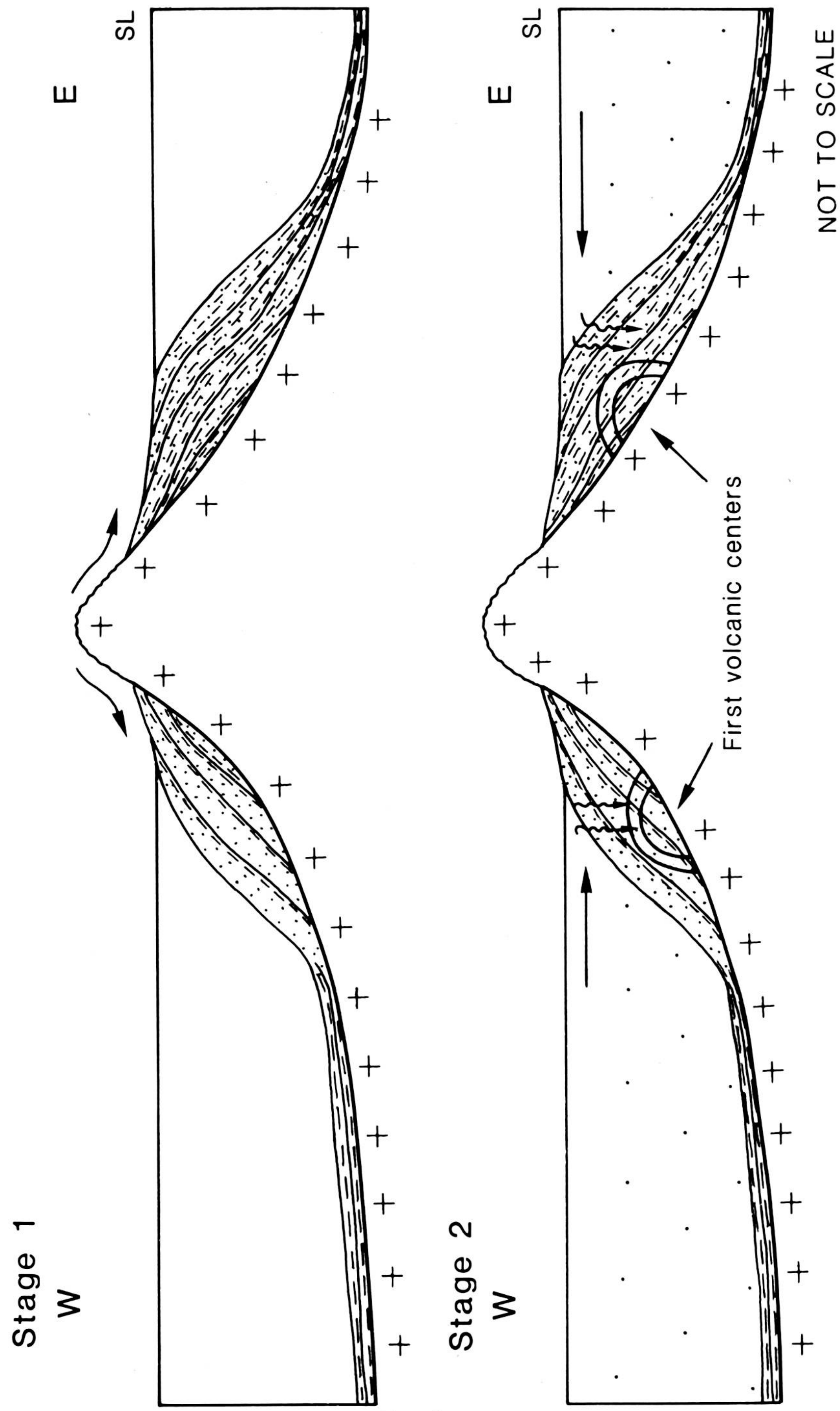

FIG. 8.

Stages 1 and 2 of the interpretation of Pallas' theory (1778). Dots in the ocean of stage 2, and in subsequent stages, represent combustible organic matter and iron generated by the decay of marine plants and animals. See text for detailed description.

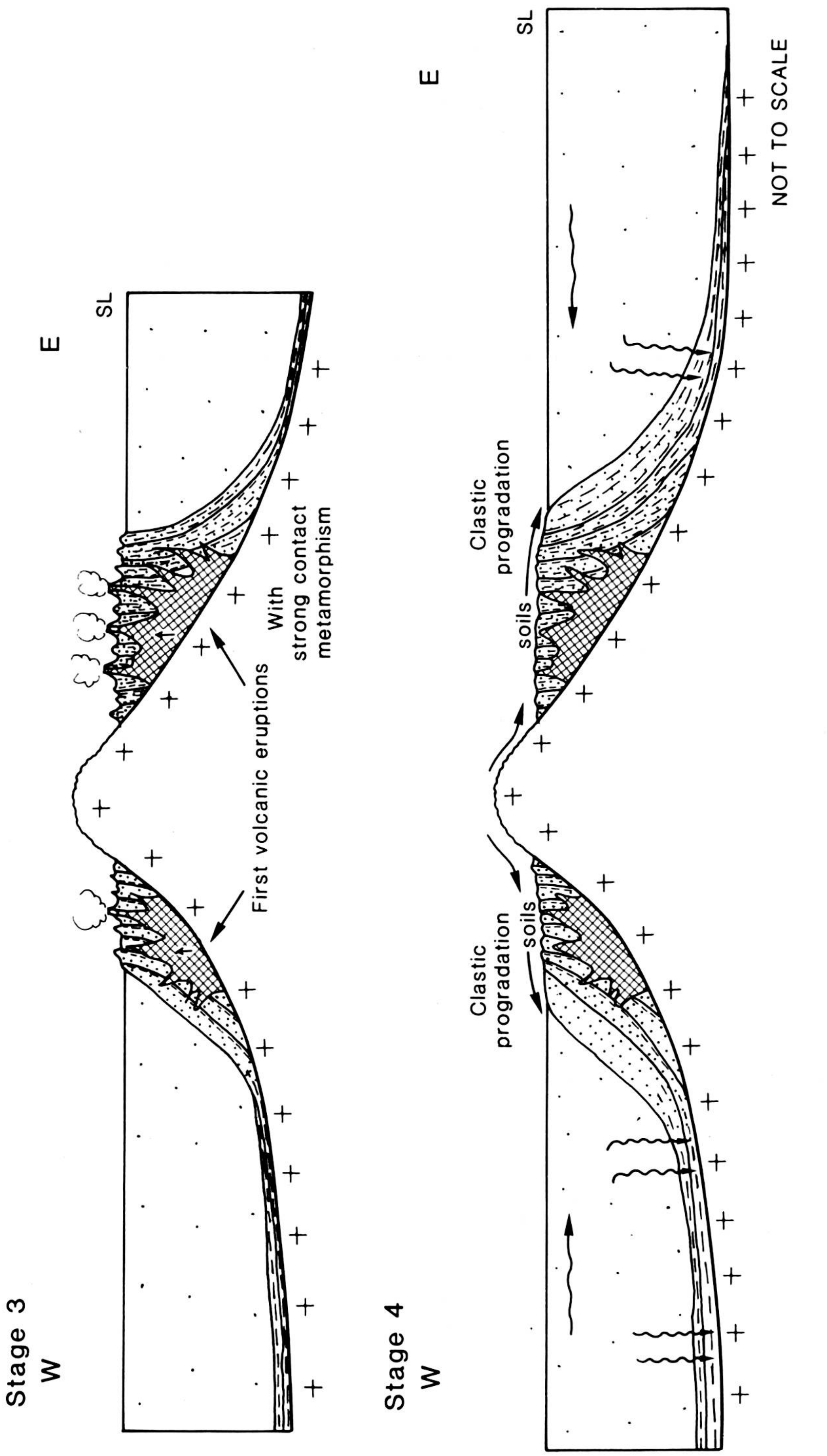

FIG. 9.

Stages 3 and 4 of the interpretation of Pallas' theory (1778). See text for detailed description.

volcanoes which were more numerous on the east side, and also to the formation of soils over both schistose bands from decaying terrestrial animals and plants.

These weathering processes generate progradational deposits of new sets of sandstones and shales which settle on the ocean floor in the usual order of decreasing grain-size oceanwards. Sandstones are more argillaceous on the east side.

The ocean still contains combustible material and iron generated by the decay of remains of marine animals and plants. These materials are again floated coastward where they infiltrate the underlying progradational distal sandstones, and mostly the shales, making them bituminous with huge concentrations of pyrite. The sites of combustion of both types of sediments mark the location of a subsequent second set of volcanic centers. Meanwhile (for the purpose of demonstration) a third volcanic center is in preparation further to the west.

Stage 5 (Fig. 10)

The next sediments are deep-water secondary limestones with abundant fossils deposited on both sides of the chain. However, on the east side, the decreased detrital supply from the destruction of mineralized metamorphic schists and numerous volcanoes is higher in amount than on the west side and very rich in volcanic materials thus giving rise to impure carbonates compared to the pure ones of the west side. The second and third volcanic centers are in their initial stages.

Stage 6 (Fig. 10)

The second phase of active volcanism on the west side uplifts the secondary limestones into a vertical position (with a minor amount of metamorphism into a marble-like aspect) next to the schistose band, and into a more gently folded pattern further westward. On the east side, a much stronger volcanic activity uplifts and folds the impure secondary carbonates which undergo at the same time strong contact metamorphic processes.

In a chronological order, the third center of active volcanism on the west side uplifts and gently folds the western portion of the secondary limestones and a completely emerged land is formed on this side of the Urals.

Stage 7 (Fig. 10)

During this final stage, the almost completed asymmetrical mountain range undergoes the action of a gigantic tsunami originating from the Indian Ocean. While crossing the entire chain from east to west, it erodes and deposits unconsolidated clastics with tree trunks, exotic plants, and abundant remains of large mammals (mammoths, rhinoceri). The deposits of this catastrophic event in the Siberian plains and over the eastern flank of the Urals are coarse gravels and sands, west of the watershed they are finer grained and still change to finer sands and clays when

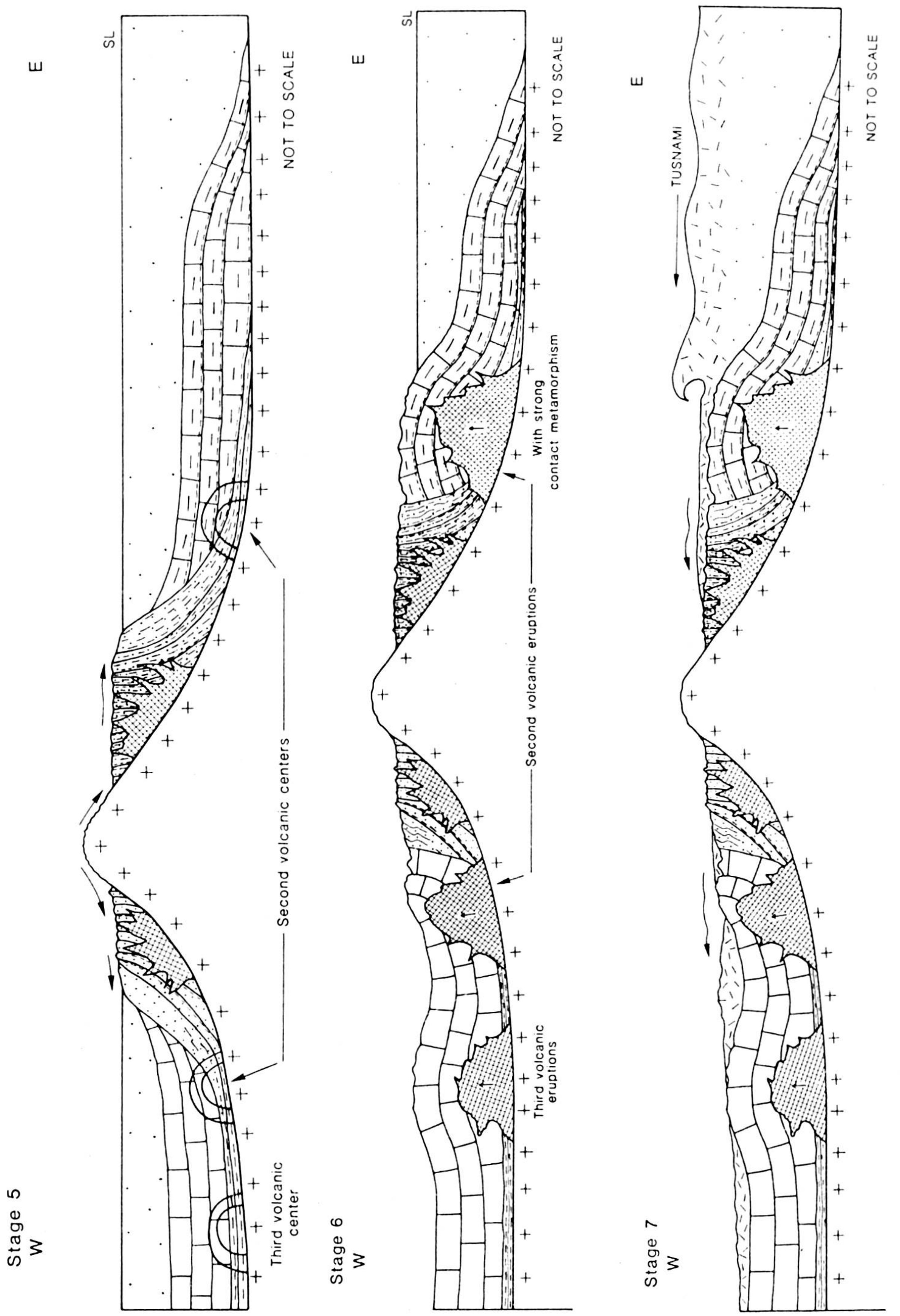

FIG. 10.

Stages 5, 6, and 7 of the interpretation of Pallas's theory (1778). Dashed lines in the tsunami waters and deposits represent exotic tree trunks and remains of large animals. See text for detailed description.

reaching the plains of Russia, and eventually the shores of the Baltic Sea. On both sides of the chain, these deposits designated simply as *Sandschiefer,* overlie unconformably all underlying folded rocks and are preserved mostly in their topographic depressions.

Concluding remarks on Pallas' geology in 1778

Pallas' map and his field descriptions show that the geology of the Ural Mountains does not correspond to his theory on mountains in general. His theory says that all major mountain chains consist of a central zone of granite followed on both sides by three major bands: primitive schistose rocks, secondary limestones, and tertiary shales and sandstones. However, neither in his summary nor in his theory did he mention any clear symmetry between the band of schists and the band of limestones on both sides of the Urals. Instead, he found non-metamorphic shales and sandstones on the west, and highly metamorphic and mineralized schists, accompanied by jaspers, marbles, and serpentines, on the east side. He also noticed well-developed limestones on the west whereas they were hardly recognizable on the east side.

Furthermore, his theory states that "the highest mountains on Earth 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, distributed randomly, in irregular fragments and various proportions, but evenly fused together" [p. 10]. He seemed to avoid the question of granite in the Urals, saying that granite formed the highest peaks 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 [p. 9]. Nevertheless, in his summary, written perhaps only in St. Petersburg, where he read or met foreign authors, he changed "vitreous rocks and quartz" for the axial chain in the Urals to "granite and other vitreous rocks" although his field descriptions made between 1768 and 1772 of the axial watershed zone of the Urals said that it consisted of gray-reddish feldspar or quartzose rocks in vertical layers (which he called the "Uralfels," namely rocks typical of the Urals). He found a small outcrop of granite at Cheljabynsk, east of the watershed, but not on the highest peaks of the Urals.

Why this inconsistency? It is probable that Pallas accepted Wallerius' terminology of granites for the Urals, without giving the precise "species" used by this naturalist (see Chapter II), because he felt he had to agree with foreign authors. Thus, he could say at the end of his theory that he suggested no more than what various famous authors had thought about the subject [p. 85].

Pallas' acceptance of what other authors said may also be attributed to political conditions and time constraints under which Pallas wrote his theory. He had to present this theory in a public lecture at the Imperial Academy of St. Petersburg for a distinguished audience which included the King of Sweden. Thus he could perhaps not contradict such great naturalists as the Swedish O. T. Bergman and J. G. Wallerius whereas he criticized Buffon profusely. Furthermore, he wrote in a letter to G. F. Müller, historian and geographer of the Academy, on July 13, 1777: ... "Indessen muss ich bitten diese flüchtige Arbeit, zu der ich nicht vierzehn Tage Zeit habe anwenden können, mit gütiger Nachsicht zu beurtheilen" (I must beg you to judge my hasty work with indulgence for I had less than fourteen days to prepare it. See Wendland, p. 93).

Our new interpretation of Pallas, based on the reading of his three volumes of travels, a careful analysis of his map, and, most important, a graphic transcription of Pallas' map based on punctual symbols of the major rocks-types into equivalent bands as in modern maps, shows that Pallas had an excellent understanding of the major structural and stratigraphic units of the Urals. These are: a discontinuous axial band of primitive vitreous and quartzitic rocks; on the west side, a discontinuous band of primitive sandstones and shales, followed by bands of first vertical and then horizontal secondary limestones; on the east side, a wide band of highly mineralized primitive metamorphic schists, accompanied by marbles, jaspers, serpentines, and intrusions of porphyritic granites, followed by a complex and poorly defined band of sedimentary and metamorphic rocks; and finally the overlap on both sides of sandy and argillaceous formations with the famous localities of mammoth bones on the Siberian side. Pallas bands of rock-types are so close to modern maps, including the bending of the chain against the Ufa plateau, that we believe that his lasting contribution to geology lies not in his hasty theory, though it explained many unrelated problems for his contemporaries with the gigantic flood, but in his careful observations of the Urals.

EPILOGUE: PALLAS' AFTERTHOUGHTS ON GRANITE (1781)

Saussure's first volume of *Voyages* which stressed the aqueous origin of granite and its deposition in layers was published in 1779. In the foreword, Saussure referred to the travels and the theory of "the famous Pallas," saying that Pallas ignored or rather "did not want to touch" mountains of granite (1779, p. XIX). Though Saussure did not challenge Pallas' concepts as he did in his unpublished critical excerpts (mentioned in Chapter IV), other naturalists must have criticized Pallas' opinion that granite never occurred in beds and that its constituents, quartz, feldspar, and mica appeared to be *zusammengeschmolzen* (fused together). One could argue that Pallas had simply not made up his mind as yet — as Saussure shrewdly mentioned — and was thus following authors who favored the origin of granite by fire. Indeed, in his theory he mentioned that "granite may seem to have been originally in a state of fusion and hence a result of fire'' [p. 11], and that characteristics of granites and schists ''seem to show that many of these rocks are the effects of a violent fire'' [p. 46]. These ideas are clearly very hypothetical. In the periodical *Neue Nordische Beyträge*... of 1781, vol. 2, p. 366-368, Pallas returned to the question whether granite occurred in large masses or in layers, and whether it was a product of fire or water, saying:

''In my *Betrachtungen über die Beschaffenheit der Gebürge* (On the Nature of Mountains) [1778] I said that primitive granite never occurs in layers. Examples against this opinion were presented and I was blamed for not having discussed this question in greater details (though I actually wrote about it in a very hasty manner because of circumstances). I had actually recognized bedded granite and mentioned in my fieldnotes the granitic peaks at the Lake Kolywan (Part II, p. 617) and the granitic mountain Adontscholo (Part III, p. 227) in Daurien [close to the Mongolian frontier].

[This is correct, Pallas mentioned near the Schlangenberg in Siberia and in the Adontscholo mountain thick inclined layers or huge flat *Wacken*.]

Nevertheless, I believe that bedded granite is not the primitive granite on Earth but a product of previously decomposed primitive granite whose debris (*Grus*) were deposited in certain areas in distinct layers which subsequently, during a new crystallization, acquired a typical granitic aspect. The formation of these rocks occurred certainly during those times when porphyry-like rocks and *Aftergranite* [newer granite] and *Gneuss* [gneiss] of the mineralogists of Saxony, and the Hungarian *Saxum metalliferum* of the famous Mr. von Born, as well as the *Granitello-und granitischen Sandsteinarten* originated.

[Pallas referred here to rocks derived by erosion and redeposition from primitive granites which subsequently were grouped by A. G. Werner (1787) under the designation of 'newer primitive': gneisses, porphyries, granitello (variety of gray, fine-grained granite, used by the Romans), and granitic sandstones. Werner considered all these rocks to be water-laid. In fact, grus is an unconsolidated weathering product of granite, called 'regenerated granite,' indurated almost in place into feldspathic wackes; granitic sandstones are massive to weakly bedded feldspathic arenites formed in alluvial fans and braided streams.]

Similarly, granite in veins, often in schists — described in an unusual example by *Mr. de Saussure* — originated at that time. [See Chapter IV, section 5, where Saussure believed in a present-day crystallization of granite-derived materials by infiltrating waters but not, as Pallas said, formed at an earlier time.]

Primitive old granite, however, is much harder, has a coarse and visibly crystallized texture, but shows no broken and rounded quartz grains. It looks as if it were poured as a mass which, although fissured, is not in parallel layers. Those who have seen high mountains have no doubts about the fact that this type of granite occurs more frequently in primitive mountains than the layered type, both on the highest peaks as in low places where it became exposed. Indeed, I had only this type of granite in mind [in my theory of 1777]. The important mines of *Bergcrystall* [well-crystallized quartz] as well as our northern Russian and Siberian *Marienglassbrüche* [selenite or transparent gypsum in large platy crystals] occur only in this kind of granite. Quartz is found there in large pure masses, forming the back of whole mountains or including large rhombohedral *(rhomboidischen)* prisms of feldspar. Along Lake Kolywan, where layered friable granite occurs frequently, primitive granite also crops out in many places. It consists of pure quartz, and often of ten to twelve feet thick whitish gray, pure feldspar crystals, and so forth. All granites which include *Schörlsäulen* [tourmaline in prismatic crystals] belong to primitive granite.

I was also blamed for referring to a vague Buffonian idea on the igneous origin of primitive material on our planet, as if I were indeed of the same opinion as Count Buffon. However, to accept this erroneous belief, I would have to close my eyes so as not to see the visible texture of so many beautifully crystallized granites which occur also in Russia. However, I would not want to be forced to decide whether crystallization of granite happened in a cold or a hot, a mush or a liquid chaos [first universal liquid]. Salt crystallizes often in thick mud and its crystals make room for themselves.''

Pallas' change of interpretation of the origin of granite shows the importance of the prevailing concept on crystallization at the time. Early experiments showed indeed that crystals of various salts could form in a liquid or aqueous environment, hence why not an aggregate of different crystals such as granite? Pallas' leaning toward the aqueous origin of granite was certainly influenced by Saussure as well as by the school of A. G. Werner whose ideas became famous long before his publication of *Kurze Klassifikation...* (1787).

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