Review of subsequent accounts of Pallas' theory

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 eastern-most 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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