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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

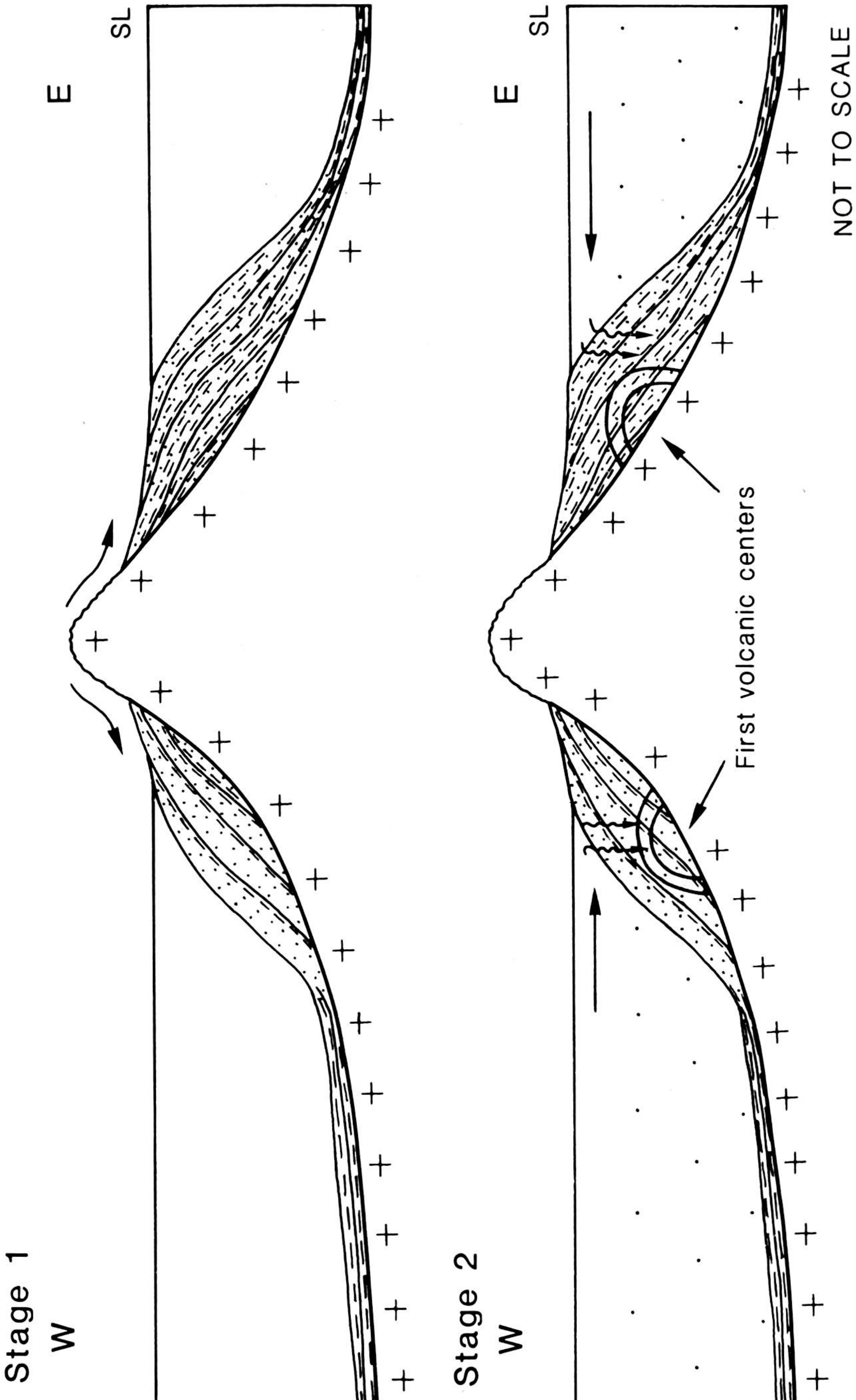

FIG. 8.

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.

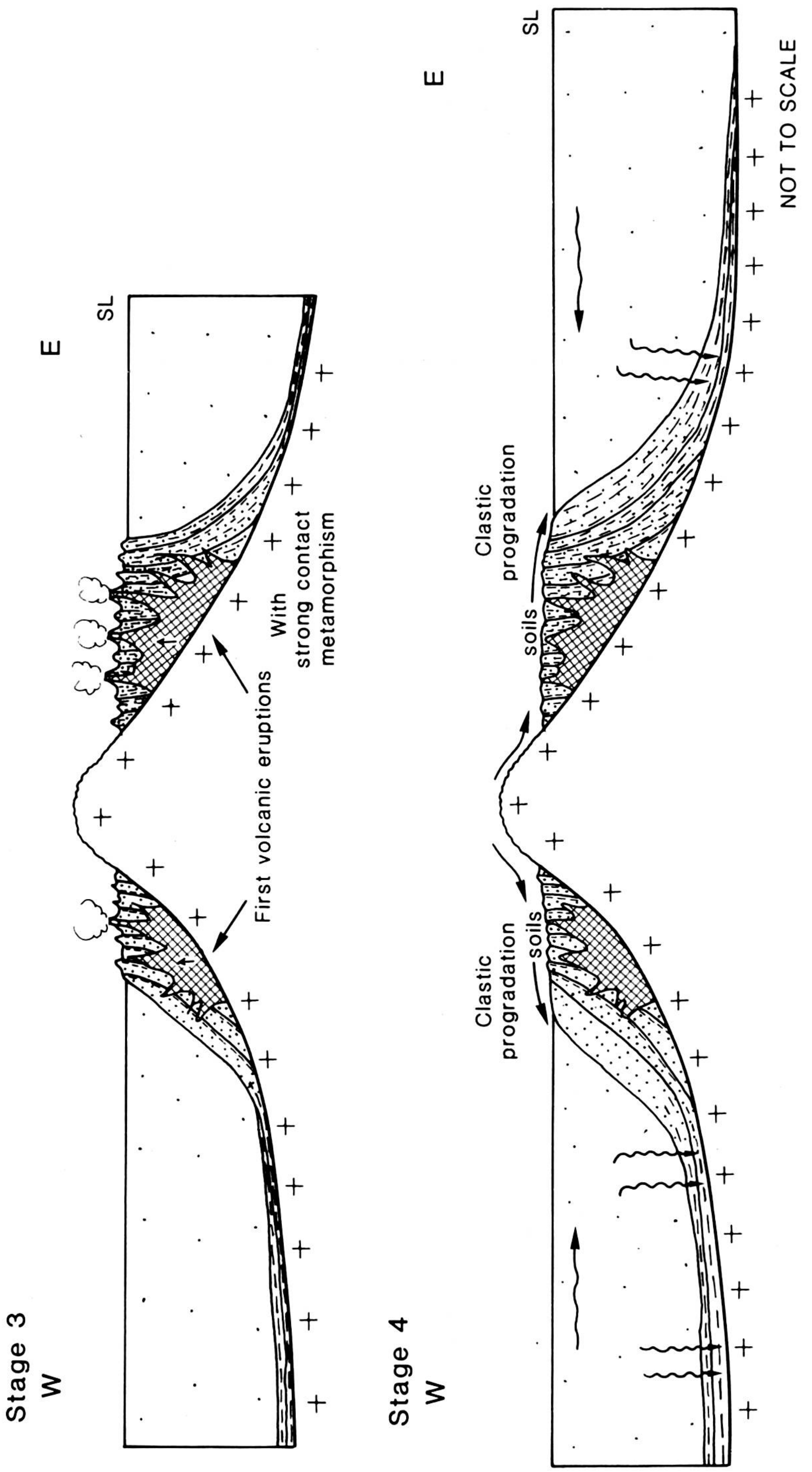

FIG. 9.

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

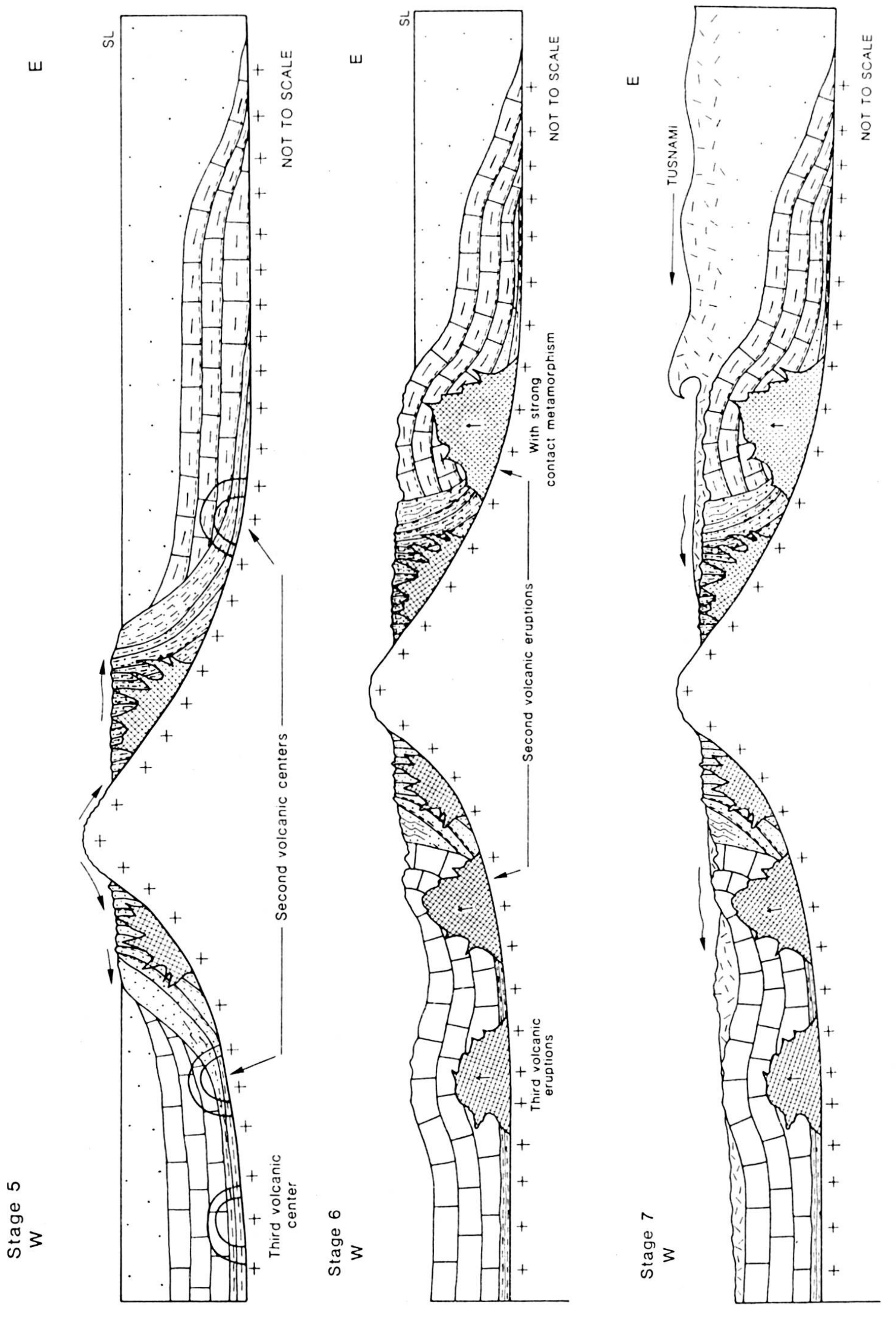

FIG. 10.

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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