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.

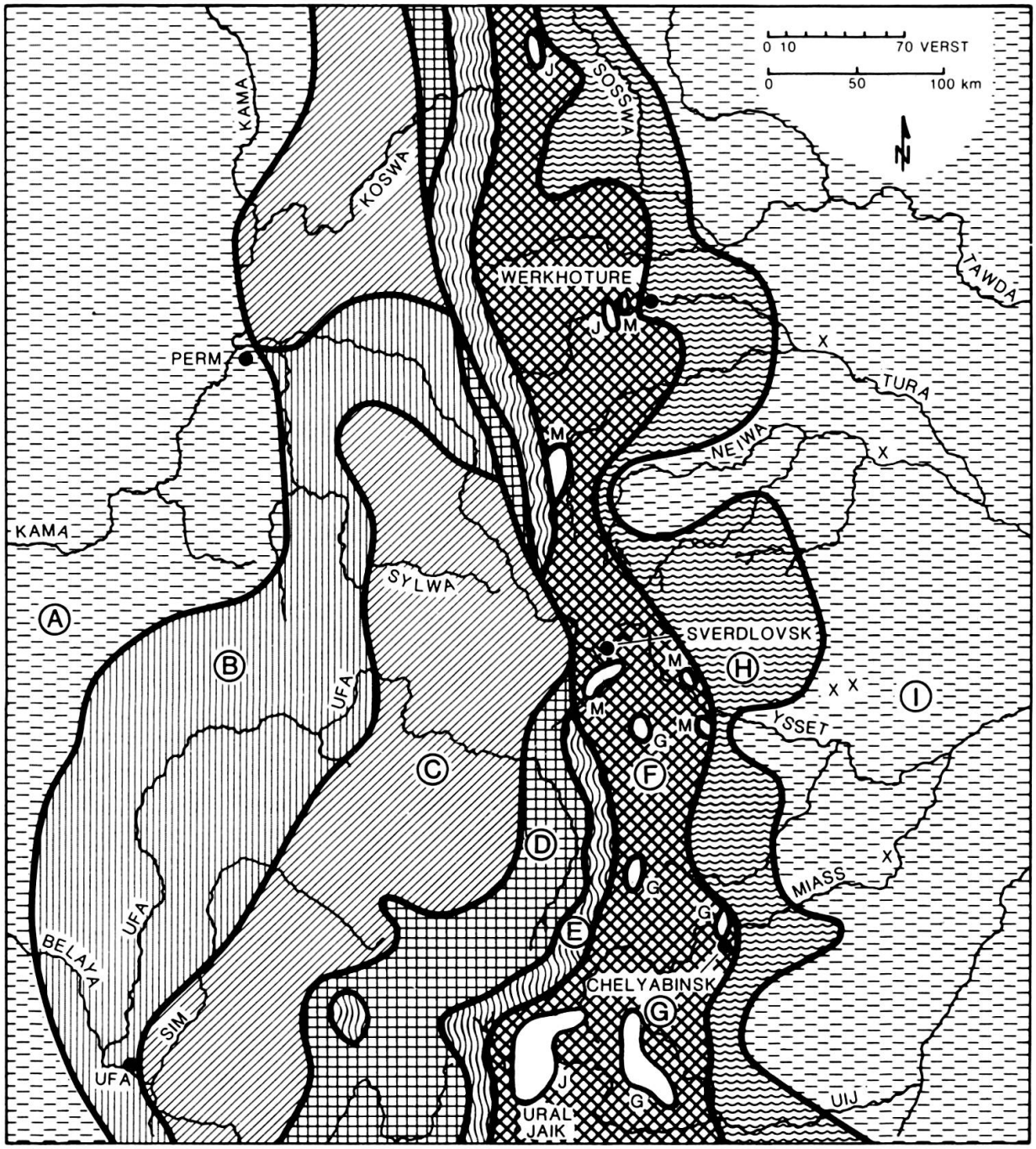

FIG. 7.

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.

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* 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.