Zeitschrift: Archives des sciences et compte rendu des séances de la Société

Herausgeber: Société de Physique et d'Histoire Naturelle de Genève

Band: 44 (1991)

Heft: 1: Archives des Sciences

Artikel: Pallas' theory of the earth in German (1778) : translation and reevaluation : reaction by a contemporary : H.-B. de Saussure

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Kapitel: IV: A contemporary critic of Pallas' theory : H.-B. de Saussure

DOI: https://doi.org/10.5169/seals-740194

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been possible to reconstruct, year by year, the precise chronological evolution of his thinking and to present what his unpublished theory, based mainly on the Alps, might have been (Carozzi, 1989).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

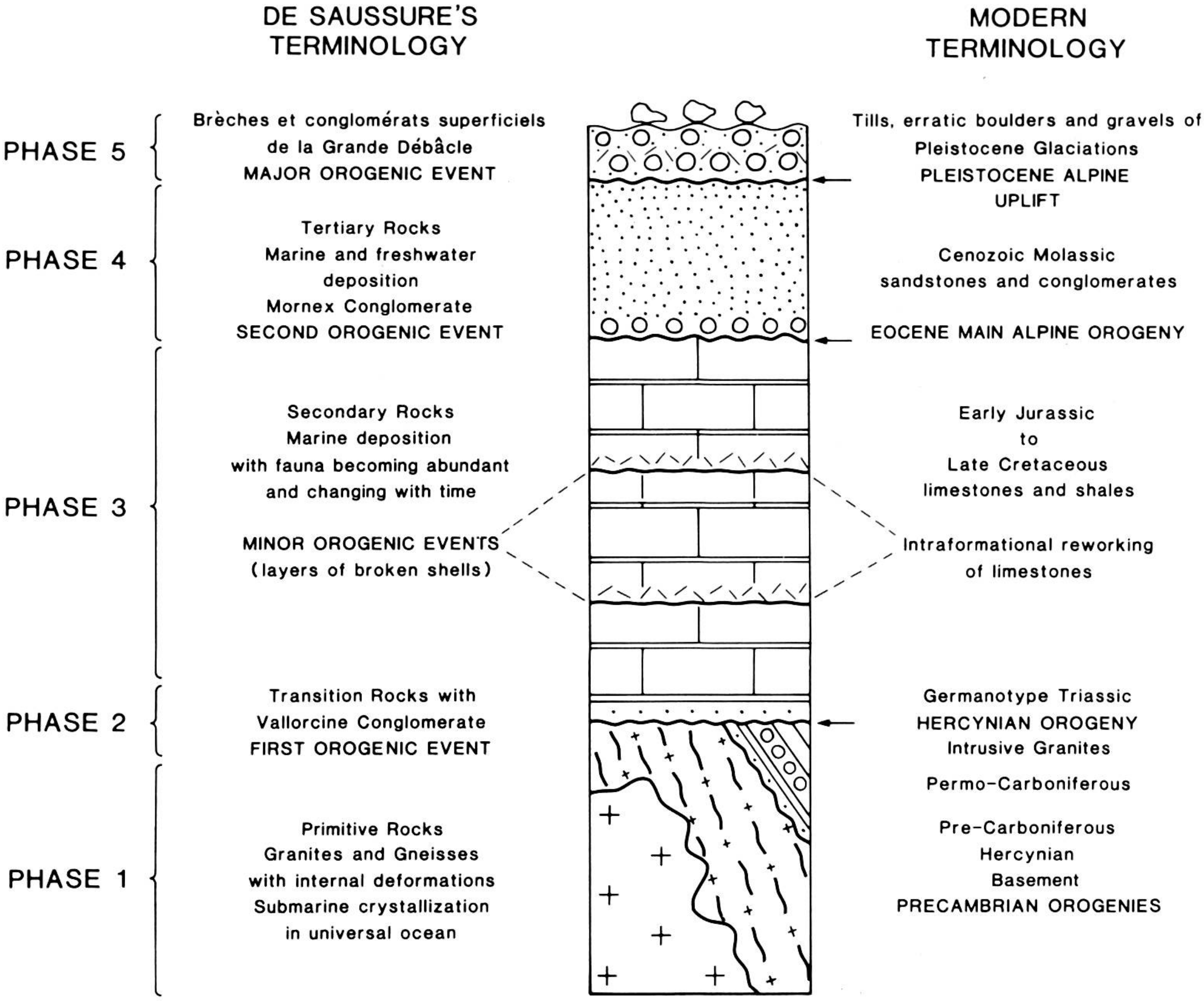

FIG. 1.

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).

REFERENCES

BEMMELEN, R. W. van (1964). Der gegenwärtige Stand der Undulationstheorie: *Mitt. Geol. Gesell. Wien,* 57, 2, p. 379-399.

BERTRAND, L. (1800). *Renouvellemens périodiques des continens terrestres:* Paris, C. Pougens, 363 p.

BONNET, Charles (1769). *La palingénesie philosophique, ou Idées sur l'état passé et l'état futur des êtres vivans. Ouvrage destiné à servir de supplément aux derniers écrits de l'auteur, et qui contient principalement le précis de ses recherches sur le christianisme,* Genève, C. Philibert, 1769, 2 vols.

BUCH, C. L. von (1810). *Reise durch Norwegen und Lappland,* Berlin, G. C. Nauck, 2 vols.

CAROZZI, A. V. (1987). La géologie. De l'histoire de la Terre selon le récit de Moïse aux premiers essais sur la structure des Alpes et à la géologie expérimentale, *in* J. Trembley (ed.). *Les savants genevois dans l'Europe intellectuelle du XVII^e^ au milieu du XIX^e^ siècle:* Genève, Editions du Journal de Genève, p. 203-265.

—— (1989). Forty years of thinking in front of the Alps: Saussure's (1796) unpublished theory of the Earth: *Earth Sciences History,* 8, 2, p. 123-140.

CAROZZI, A. V. and J. K. NEWMAN (1990). Dialogic irony: an unusual manuscript of Horace-Bénédict de Saussure on mountain building: *De Montium Origine* (1774): *Archives des Sciences Genève,* 43, 2, p. 235-263.

HAARMANN, E. (1930). *Die Oszillationstheorie.* Stuttgart, F. Enke, 260 p.

SAUSSURE, H.-B. (1778). *Extraits raisonnés,* Vol. 1. *Pallas Travels,* vol. 1, excerpt No. 77, p. 50-53; vol. 2, excerpt No. 78, p. 54-74; vol. 3, excerpt No. 79, p. 75-86 (completed October 2, 1778). *Pallas Theory of the Earth,* excerpt No. 84, p. 100-123 (completed November 17, 1778): MS-Saussure No. 81, Public and University Library of Genève.

—— (1778). *Idées détachées qui doivent servir à mon ouvrage sur les montagnes:* MS-Saussure No. 91, 19 p. Public and University Library of Genève.

—— (1779-1796). *Voyages dans les Alpes, précédés d'un essai sur l'histoire naturelle des environs de Genève.* Neuchâtel, S. Fauche, 4 vols 4°.

STÖSSNER, Arthur (1900). *Pallas Ansichten über einzelne Kapitel der Physischen Erdkunde. Ein Beitrag zur Geschichte der Geographie.* Inaugural Dissertation for the degree of Doctor of Philosophy, University of Leipzig, Department of Philosophy. Eibau i.S.: Adolph Mehnert, 53 p.