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Autor: Carozzi, Albert V. / Newman, John K.
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DIALOGIC IRONY: AN UNUSUAL MANUSCRIPT OF HORACE-BÉNÉDICT DE SAUSSURE ON MOUNTAIN BUILDING: *DE MONTIUM ORIGINE* (1774)

BY

Albert V. CAROZZI * and John K. NEWMAN **

ABSTRACT

This interdisciplinary approach sheds light on a previously unknown side of Saussure's intellectual approach to science. The dialogic style of *De Montium Origine* (1774), reminiscent of Plato's Socrates who preserved a certain distance from his audience, is mirrored in Saussure's attitude toward a coached student asking, in a class exercise typical of a philosophy course, an important question which generates a lengthy reply by the professor. Based on his geological knowledge and his recent trip to Italy, the professor discusses the formation of mountains according to a strict Neptunian approach, and consequently rejects the existence of a central fire and the role of volcanism in mountain building as proposed by Lazzaro Moro and Giovanni Arduino.

In contrast to the *Voyages dans les Alpes*... Saussure refers to many contemporary and earlier authors of theories of the earth, but never strays from the Neptunian system. However, the professor does not reveal his revolutionary ideas on the formation of the Alps reached that same year, put in final shape in 1778, and published only in 1786, namely the uplifting and upturning of the primitive bedded granite by the explosion of elastic fluids. Obviously, Saussure, like Socrates, remains aloof from his students and silent on his latest interpretation of the subject.

RÉSUMÉ

Cette étude interdisciplinaire montre un aspect inconnu jusqu'à ce jour de l'attitude intellectuelle de Saussure envers la science. Le style en forme de dialogue de *De Montium Origine* (1774), rappelant le Socrate de Platon qui gardait une certaine distance de son public, est reflété dans la position de Saussure par rapport à un étudiant, bien averti d'avance, dans un exercice de classe typique pour un cours de philosophie. L'étudiant pose une question fondamentale qui donne lieu à une longue réponse du professeur, basée sur ses connaissances géologiques et son dernier voyage en Italie. Le professeur discute la formation des montagnes suivant un point de vue strictement neptunien, et par conséquent rejette l'existence d'un feu central et le rôle du volcanisme dans la formation des montagnes proposés par Lazzaro Moro et Giovanni Arduino.

* Department of Geology, University of Illinois at Urbana-Champaign, Urbana, Illinois, 61801-2999, USA.

** Department of the Classics, University of Illinois at Urbana-Champaign, Urbana, Illinois, 61801-2999, USA.

Contrairement au texte des *Voyages dans les Alpes...*, Saussure mentionne de nombreux auteurs anciens et contemporains de théories de la terre, mais ne s'écarte jamais du système neptunien. Ainsi, le professeur ne révèle pas ses propres idées révolutionnaires sur la formation des Alpes formulées cette même année, mises en forme finale en 1778, et publiées seulement en 1786, à savoir le soulèvement et la mise en position verticale des couches de granit par l'explosion des fluides élastiques. Il est évident que Saussure, comme Socrate, montre une attitude réservée par rapport à ses étudiants et reste silencieux sur sa propre et dernière interprétation du sujet.

INTRODUCTION

From the unpublished works of Horace-Bénédict de Saussure (1740-1799), we are presenting here a transcript and a translation into English followed by a discussion and endnotes of an unusual manuscript entitled *De Montium Origine,* 1774 (On the origin of mountains) preserved at the Public and University Library of Geneva.

The literary form consists of a question from a student in philosophy which gives the opportunity to his professor for a long reply (oration) based on his experience in geology and his recently completed trip to Italy. Contrary to Saussure's major work *Voyages dans les Alpes...* which contains few references to previous or contemporary authors, *De Montium Origine* discusses numerous authors of theories of mountain building, and presents a detailed refutation of the existence of a central fire and the role of volcanism in the formation of mountains.

SAUSSURE'S SCIENTIFIC ACTIVITY UNTIL 1774

In 1759, H.-B. de Saussure completed his degree in philosophy at the "Academy" or University of Geneva with a dissertation on the transmission of heat from the sun's rays: *Dissertatio Physica de Igne.* The following year marks the beginning of his numerous trips to Chamonix, at the foot of Mont-Blanc, with the purpose of collecting plants for the famous physician and botanist Albrecht von Haller who exerted a strong influence on Saussure's early life and career.

Saussure became a candidate for the chair of mathematics at the Academy in 1761, but was defeated by Louis Bertrand who in 1800 would also write on geology. In consolation, Saussure turned to the study of Classical authors, having always supported the importance of humanities in a scientific education. He also continued his investigations in botany and published in 1762 a major work entitled *Observations sur l'écorce des feuilles et des pétioles des plantes* dedicated to A. von Haller.

In 1762, the chair of philosophy became vacant. Philosophy at the Academy of Geneva included psychology, logic, morals, and divinity and also the general principles of the natural sciences with some acquaintance with the ideas of Bacon, Descartes, and Leibniz. Each candidate for the chair had to present two short theses or discussions, one on philosophy and the other on natural sciences. Saussure wrote

on *The principal causes of errors arising from the quality of the mind* and *On rainbows, halos and parhelia,* to which he added his 1762 book on botany. His candidacy was strongly supported by A. von Haller, and after a hot contest Saussure was elected to the chair. One year he lectured in French on physics and natural history, and the other in Latin on metaphysics and philosophy.

In March 1764, Saussure undertook another trip to Chamonix where he saw for the first time the glaciers under snow. Although not abandoning botany completely, he decided to shift his interest to geology in order to understand the history of the planet, and also to meteorology as a key to its morphological evolution. He also became convinced that an understanding of the formation and structure of the Alps was critical in grasping the history of the whole planet. For that purpose he planned to undertake an Alpine tour every year and almost kept his word until 1789.

His serious travels began in 1767, interspersed by a "grand tour" with his wife to France where he met Buffon, Nicolas Desmarest and Jean-Etienne Guettard and to Great Britain in 1768, and by a trip to Italy between October 1, 1772 and August 22, 1773. In Italy, he visited Torino; Milano; Bologna; Firenze; Livorno; the iron mines of the island of Elba; Roma; and Napoli where Sir William Hamilton was delighted to guide him on a visit to Vesuvio and the Campi Phlegraei. Then Saussure went to Sicily where he climbed Etna on June 5, 1773. His return trip took him back to Napoli and Roma; then to Ancona; Venezia where he met Giovanni Arduino; to Trento; the Brenner Pass; the Alps of Tyrol; and back to Geneva.

The Saussure Archives at the Public and University Library of Geneva (BPU, MS 99) contain an abstracted itinerary of this trip and a rough draft of Saussure's observations and comments entitled "Notes sur l'Italie". These, unfortunately, were not recopied as he did on subsequent trips within 24 hours of the field observations. These notes are written with a very fine pen, almost washed out today and extremely difficult to read (AVC in progress). Fortunately, some aspects of the return trip from Napoli to Geneva are included in Saussure's letter to Hamilton on the physical geography of Italy, dated December 17, 1774, and published in 1776.

Upon his return from Italy, Saussure was appointed Rector of the Academy, a position he held until 1776 while continuing his teaching. It is during this interval of time, namely in 1774, that *De Montium Origine* was written and remained in manuscript form. Its writing seems to precede his first geological publication, the above-mentioned letter to Hamilton.

ORIGINAL LATIN TEXT OF *DE MONTIUM ORIGINE*

Notes on Style

The lecture is cast in dialogue form. This is not haphazard. Saussure had been a student of the Classical authors, and here we find that certain typical features soon

make themselves apparent: the description of the beauties of nature which form the background to the discussion; the modesty of the author, who does not dare to advance his own conjectures and whose rash adventure on Vesuvio allegedly put his life at risk; the largely negative nature of the argument, which in turn generates a certain scepticism about the traditional cosmogonies; and the concluding piety. There is also the implicit comparison of Geneva to Rome/Athens. Saussure twice, for example, refers to Geneva as *Urbs* which in classical Latin could only indicate Rome, and his interlocutor describes the gathering assembled to hear the professor as a *selecta coronis,* where *coronis* is a catachrestic Grecism for the expected *corona.* Elsewhere, this same gathering is a *panegyris.*

Although the author of the lecture, as part of his generic stance, apologizes for his plain style and for the absence in it of the refinements of the Latin language, he writes correctly and idiomatically, if not wholly classically. He allows himself, for example, the licence common in academic Latin of *quod* to introduce indirect speech, and his report of Lazzaro Moro's views is given in *oratio recta,* rather than the more classical *oratio obliqua.* Even so, his narrative is not without an occasional poetic touch, for example, at the beginning and the end, where he moves from the contemplation of the natural beauty of the Swiss Alps to the realization of the immense aeons of time occupied by the formation of the Primary and other mountains. His description of his adventure on the top of mount Vesuvius, where he describes himself as actually in some danger, is quite vivid.

The lecture displays a certain classical learning. Saussure has heard of the Carthaginian assault on Syracuse, and he knows what the Greek name is for "granite", and what the ancient name for Solfatara was.

There is also some use of classical rhetoric. The style is periodic, and we find anaphora, homoeoteleuton, asyndeton, antithesis, crescendo, rhetorical question. In particular one notes verbal repetition, whether consciously intended or not. Thus the lecture begins and ends with amazement (*stupendo... obstupescit*), at the Alps and at the scale of geologic time. Another repeated allusion at the beginning and end is to the *histories* of the ancients. Elsewhere, the author first of all describes the *industria* of the emperors in bringing the Egyptian obelisks to Rome, and later the humbler but perhaps more useful *industria* of the peasants in bringing soil to turn volcanic lavas into productive land.

His use of dialogic form, though hallowed in academic circles ever since Plato, has an immediate relevance. It enables him to maintain a certain Socratic distance from his audience. The statement that he has "rather unlearned errors than learned the truth" is particularly reminiscent of Plato's Socrates. Hence the emphasis on the refutation of others rather than on the presentation of his own views is quite consistent with his chosen medium. So is the elaborate courtesy extended to Sir William Hamilton, whose theory turns out to be misleading as pointed out below. So is Saussure's own self-deprecation and the quasi-religious *aporia* of the end.

None of these ironic nuances is easily conveyed in translation only, and so it seemed advisable to offer a transcription of the Latin text (copied by an amanuensis who may have been guilty of certain negligences), accompanied by a plain translation to guide the reader whose Latin may need some assistance.

Quaestio *

Dum in paternis hortis ad amoenissimam Lacus nostri ripam sitis ambulo, pulcherrimus in Orientem patens prospectus me semper cum admiratione delectat; sed inprimis ubi sol planitei respectu iam occasus, radios vaporibus ref<r>actos in excelsa montium cacumina vibrat, aeternasque Alpium nives igneo colore tingit, stupendo spectaculo suspensus haereo, nec oculos avertere possum.

Ne tamen credas, Vir Orn<atissime> me colorum pulchritudine totum detineri. Mecum interea cogito, quam alti sint isti montes, quam longe lateque extensi: cumque Philosophiae studium in rerum causas investigandas animum convertat, enormium istarum molium originem et formationem cognoscere aveo. Quapropter, Burnetum, Whistonem, sed inprimis Cl<arissim>um Buffonium, avide evolvo; sed ingeniosas potius fictiones, quam fidelem Naturae interpretationem in eorum systematibus inveniens, in dubium ignorantiae anteponendum continuo relabor.

Audii vero natam in Italia singularem Hypothesim, quae montium omnium originem subterraneis ignibus tribuit; eamque ab Illustribus Viris nuper adoptatam, novisque observatis exornatam fuisse. Quae cum minus cognita sint, quaeso, Vir Ornat<issime>, ut quid de illis in itineribus audieris, quid etiam naturam investigando verum esse compereris, et mihi et huic selectae Coronidi impertiaris.

Oratio

Me quoque, Ornat<issime> Phil<osophiae> Candidate, magnificum stupendumque Alpium nostrarum spectaculum saepissime detinet et in profundas meditationes conicit. Nec mihi, plusquam tibi, ingeniosa auctorum systemata satisfecere.

Et licet ipse tot montes lustraverim, licet Alpes per quinque diversos transitus traiecerim, pluriesque et in imis vallibus et in summis iugis pererraverim, vix tamen coniecturas adferre ausim, quae laudatorum virorum coniecturis certiores mihi ipsi videantur. Iis enim laboribus, potius errores dedidici, quam veritatem didici.

Ne igitur doctam hancce Panegyrim teque, Orn. Adol., cognitorum systematum cognitis vitiis, vanisve meis coniecturis detineam; certiora tum de montibus in genere, tum de vulcaniis observata tradam et simul Italicam hypothesim, cis Alpes vix cognitam explicabo, et perpendam. Sed neque Latini sermonis elegantias, quas invita Minerva adfectarem, nec oratorium stylum in Physica disquisitione expectes; dispositе clare et breviter quantum potero edisseram.

* In the transcription of the text, angle brackets (< >) indicate an insertion necessary to supplement the sense. Square brackets ([ ]) indicate a deletion. The punctuation of the original, when it would mislead a modern reader, has sometimes been changed. Latin orthography has largely been standardized.

Nescio an merum sit humani cerebri commentum, an vastissimi incendii, vel antiquorum vulcaniorum memoria; sed certum est, universalem Mundi deflagrationem, universali Diluvio anteriorem, in antiquorum populorum historiis memorari. Eaque videtur fuisse causa, cur Zoroaster, Pythagoras aliique veteres Philosophi Universi originem ab igne repetierint.

Inter recentiores autem nonnulli qui Cosmogonias scripserunt non totius quidem Universi, sed saltem Telluris nostrae primitivum statum igneum fuisse contenderunt; uti Cartesius, Leibnitzius, Buffonius. Alii, omissa quaestione de primitivo statu, ignem perpetuo ardentem quam Centralem dixerunt in Telluris visceribus supposuere; uti Kircherus, et nuper magno Physices detrimento extinctus D<omi> n<u>s de Mairan.

Primus autem, quod sciam, celeber Venetus nomine *Lazaro Moro* istos subterraneos ignes ad montium originem explicandam adhibuit.

Cuius systema, ut melius intelligas, Iuv. Orn., certiusque de illo iudicium feras, generalem montium structuram dispositionemque, qualem et aliena et propria observata eam se habere docuerunt, paucis tibi exponam.

Tellurem nostram undique cingunt magni continuique montium tractus, quos Gallice dicimus *des Chaînes de Montagnes; comme les Cordillières, les Alpes, les Pyrénées.* Unusquisque ex iis tractibus, pluribus constat montium ordinibus lineisve, inter se quidem parallelis, sed natura uti et altitudine prorsus diversis.

Mediam altissimamque lineam occupant montes *primarii* dicti, quales sunt in Alpibus nostris, *le Saint-Gothard, le Mont-Blanc, le Mont-Cenis.* Eorum materies fere ubique singulare est lapidis genus, recentioribus *Granites* dictum, quia granulis formatum adparet: Graecis *pyrrhopoecilon* dicebatur, quasi igneo colore varium, Latinis vero *Syenites,* quod iuxta Syenam Thebaidis urbem secaretur. Nostratibus *Serpentin* ob serpentinas maculas; Gallis vero *granit,* cum apud eos vox *Serpentin* aliud lapidis genus indicet.

Non semper granis, sed etiam laminis filamentisve primariorum montium materia composita videtur; sed istae partes cuiuscumque sint formae, semper diversam in eadem massa naturam, diversosque colores exhibent; semper angulosae et tamen accurate sibi invicem convenientes, sine ullo visibili caemento connectuntur; semper acidis liquoribus resistunt, et igne intensissimo non in calcem, sed in porosum vitrum mutantur.

Quaedam vero genera tam firma compage gaudent, ut aeris iniuriis temporique cuncta consumentibus ultra modum resistant. Quapropter ab antiquis Aegyptiis aeternitatem in operibus suis tam superbe adfectantibus, quique pulcherrimum ignis colore splendens huius lapidis genus in Thebaide superiori deprehendebant, ad omnia opera maiora semper adhibebantur. Quo autem successu, intelliges, Orn. Adol., ubi dixero, Syenitas obeliscos, Imperatorum magnificentia incredibilique industria Romam translatos, figuris insculptos esse, quarum anguli adhucdum aeque acuti sunt, ac si acutissimo ferro novissime secti fuissent.

In hoc autem maximam attentionem merentur granitei montes quod non sint sicuti ceteri montes parallelis et regularibus stratis distincti; sed in enormes massas congesti, cum fissuris hinc et hinc sine ordine dispersis.

Insignes etiam sunt, eo quod diversi generis montes eorum radicibus superpositi videantur, ipsi vero aliis nunquam insistant. Fragmenta et magna quidem huc et illuc translata et in ipso lacu nostro deprehendas, sed genuinos ex hoc lapide montes alieno solo insidentes nullibi reperias. Praeterea, nulla unquam corpora alienigena, nec plantarum nec animalium quorumcumque partes, in graniteorum montium visceribus, vel in ipso huius lapidis corpore deprehenduntur. Quae observata, eos montes lapidesque ceteris antiquiores esse demonstrantia, *Primariorum* nomen propter antiquitatem sicuti ob duritiem et altitudinem ipsis iure merito datum fuisse ostendunt.

Montes *Secundarii* minus duri, minus antiqui, minus alti, potissimum ex lapide calcario uti Saleva noster et Jura, vel ex ardesiis constant, primariorum radicibus vulgo insistunt, et in ordines ipsis parallelos dispositi sunt. Stratis distinguuntur, quae nisi terrae motibus fracta vel perturbata fuerint, parallelismum et inter se et cum horizonte servant. In eis omnibus, vegetabilium vestigia, vel ipsas animalium praesertim marinorum exuvias, oculus attentus detegit; tantaque in quibusdam calcareis montibus frequentia, ut multi Physici primam calcareorum lapidum materiem in conchis et coralliis unice quaerant.

Tertiarii montes, primariis secundariisque humiliores, eorum ruinis et fragmentis constant, nunc liberis solutisque, nunc in lapideam duritiem adglutinatis; strata etiam parallela sepultasque animalium et vegetantium exuvias exhibent.

In omni igitur spectabili montium tractu, *primarii* montes centralem altissimamque lineam efformant; *secundarii* ipsis attigui inferiores sunt; tertiarii tandem per gradus ad planities usque descendunt. Ipsaeque planities vallesque mixtis omnigenorum montium fragmentis aquarum vi translatis et rotundatis replentur; sicut in Lacus, Rhodani, Arvaeque ripis et in Collibus Urbi nostrae vicinis videre est.

Minores autem montium tractus uti Apennini et Jura primariis montibus destituuntur secundariisque et tertiariis solummodo constant.

Nunc, Ornat. Adol., cognitis generalibus montium differentiis, celebris Itali systema facilius intelliges. Supponit ingeniosus auctor terram recens creatam perfecte sphaericam et aquis dulcibus coopertam, eiusque fundum idem fuisse saxum, quod primariorum montium materiem constituit. Tertio autem Creationis die — nam systema suum Mosis narrationi adcommodare intendit — ingentes ignes in telluris gremio accensi primarios montes, maris fundum prius constituentes, sursum protuserunt. Cumque non integri, sed rupti fissique prodierint, per hiatus et fissuras exaestuantes proruperunt ignes, qui cineres omnigenasque materias in aëra vibraverunt: eaeque materiae in mare recidentes in horizontalia strata sponte sese disposuere, et montium secundariorum stratificata corpora efformavere. Effusis etiam ab igne salibus, mare salsum factum est, et a Summo Numine creati pisces qui illud incolerent. Sed mox sub novis montibus adhuc mari coopertis novi accensi sunt ignes, qui ipsos

simul cum conchis piscibusque sursum extulere. Sic continentes et insulae ex aquis enatae sunt, sicque mare iustos intra limites contentum. Interim super arida saxa formata est humus et crevere plantae. Sed nova etiam aperta sunt ignivoma ora, quae cineres evomuere, novosque montes efformavere sepultis vegetantibus refertos. Sic intelligitur quare secundarii et tertiarii montes stratis distincti et adventiciis corporibus intermixti appareant, dum contra primarii unico supremae Voluntatis actu simul cum Universo creati, nulla successivae formationis signa exhibent.

Ista finxit Morus, sed eius fictio multis respectibus infirma visa est.

Primum obiecerunt, plurimis in secundariis montibus marinas conchas, pisces, aliaque adventicia corpora, non ut a violento motu convulsa et confuse sepulta, sed in familias disposita et in situ naturali collocata reperiri, prorsus ut in locis natalibus inveniuntur: ita ut hi montes et hoc et aliis respectibus lenti et regularis incrementi longas saeculorum series requirentis manifesta indicia ostendant. Observatum est etiam, quod exceptis antiquis recentibusque vulcaniis montibus, reliqui omnes nullas vitreas et ab igne mu[l]tatas materias continent; cum primarii granitibus constent, et secundarii ardesiis calcariisque lapidibus qui nihil ab igne passi sunt.

Haec obiectio, quae ex calcario lapide plurimos secundarios montes constituente deducitur, singulari observatione resoluta visa est.

Nobilissimus Eques Hamilton antiquitatum cognitione et singulari naturae studio non minus quam natalium dignitate et Britannica legatione insignis illius observationis primus auctor est.

Physicis omnibus cognitus est locus prope Neapolim situs, indigenis *Solfatarra* dictus, indubitatisque signis antiqui vulcanii os, vel uti dicunt *Craterem* prodens. Est scilicet exigua planities, continuato rotundo colle, ex lapidibus liquefactis quas *lavas* vocant, pumicibusque circumcincta. Hic locus *Forum Vulcani* antiquis dictus est forsan ob flammas eorum tempore adhuc erumpentes.

Nunc non amplius flammae, sed calidissimi fumi ex lavarum fissuris foraminibusque exeunt, hic aquei et dulces, hic acidi <et> suffocantes, incensi sulphuris fumo ad amussim similes. Tales fumos eructant omnes vulcanii. Ipse dum in altissimo Vesuvii limbo starem, sulphureo densissimo fumo subito erumpente fere suffocatus et atra caligine circumdatus, de via ad vitam fuga servandam tenenda anxius haesi. Similem etiam fumum in summo Aetnae cacumine sensi, sed minus suffocantem; cum enim Aetna triplam fere Vesuvii altitudinem habeat, uti barometrica observatione deprehendi, graviores acidae particulae sensim adscendendo relabuntur. Observavit autem Ill<ustris> Eques Hamilton et mihi tum in Solfatarra tum aliis in locis ostendit, sulphureos istos fumos, ubi pumicibus vel lavarum fragmentis occurrunt, ea sensim corrodere, emollire, nigrasque et duras lavas in albissimam terram convertere.

Quin immo alba ista materies solis calore exsiccata, in pulverem album calci simillimum fatiscit, qui pluvialibus aquis ablutus, et in locis inferioribus depositus, tandem indurescit, variosque adsumens colores marmora et alabastra venis coloribusque mentitur.

Inde nascebatur suspicio materias olim iuxta Mori fictionem ab igne vibratas combustionis signa amittere et in calcem mutari potuisse. Verum diligentiori inquisitione compertum est, terram istam, pulveremque et massas ex ea formatas non calcem, sed argillas esse, genus terrae a calce diversissimum.

Haec igitur Illustris Equitis observatio quae lavarum in terras ab acidis fumis conversionem demonstravit, licet omnino nova et momentosa, nulla tamen ratione infirmum Mori systema stabilire potest; semperque pro certo habendum, *secundarios* montes incrementa sua sub ipso mari, terrae, concharum et plantarum lenta et successiva depositione sumpsisse.

Neptuno igitur *secundariorum* montium tertiariorumque ipsis adeo similium reddita est creatio. *Primarios* autem Vulcano adservare novis conatibus tentaverunt. Insignis Physicus Lazari Mori conterraneus et adhuc uti spero Venetiis florens, *Johannes Arduini,* Euganeos colles Patavii vicinos olim ignivomos totosque ab igne productos fuisse demonstravit, singularesque detexit lavas quibusdam granitibus valde similes; unde pro verisimili habet, *primarios* montes a subterraneis ignibus olim intra telluris gremium concoctos, et tandem elatos fuisse.

Quin etiam, contendit, *primariorum* montium declivitates ab omni parte versus planitiem inclinatas esse, quasi montes dum ex terrae visceribus sursum propellabantur saxeam telluris crustam adscendendo sublevassent. Et revera sic inclinati montes nonnullis in locis occurrunt, sed contraria directione tanto numero deprehenduntur, ut ista observatio solidum systemati fundamentum subpeditare non valeat.

Quod similitudinem lavas inter et granitas observatam spectat, ea nec universalis est nec accuratam comparationem sustinet; ignisque lavas istas aliter ac genuinos granitas adficit.

Praeterea numquam in granitibus observantur istae rotundae bullae, quas Physici[s] poros igneos dicunt, quasque in vitro, omnibusque materiis huius generis et in ipsis lavis adeo frequenter deprehendimus.

Quapropter ab Italico systemate prorsus recedens, granitis primariorumque montium formationem nequaquam igni tribuam, potiusque sub aquis formatos cens<e>am, cum toti referti sint immo et compositi huius modi crystallis, quae in aquis non vero in igne concrescere solent. Sed in re adeo incerta demonstrationem, ipsiusque formationis modum, vel tempus, quaeso ne efflagites.

Nihilom[n]i<n>us tamen certum est, subterraneos ignes, maximam tum in procreandis tum in mutandis montium formis vim exercere. Licet enim nulla eorum vestigia in Urbis nostrae vicinitate nec in montibus adiacentibus hucusque reperta fuerint, in omnibus tamen mundi partibus antiquorum vulcaniorum indubitata quotidie deteguntur indicia, vastaeque regiones et insulae permultae totae <sunt> vulcaniae.

Quandoque etiam mixtae reperiuntur maris et ignis reliquiae. Sic in insula Ischia, Pythecusis olim dicta, et in collibus Romae vicinis, pumicum et lavarum strata, lapidum conchyliorumque marinorum stratis alternatim interposita vidi, ita ut isti

colles alternis Vulcani et Neptuni laboribus formati appareant. In Vicentinis autem Alpibus, medios inter calcareos montes, olim nuperque proruperunt ignes, et liquidae lavae per calcareorum stratorum interstitia transsudaverunt.

Cumque in omnibus Divini Numinis operibus aliquam nobis destinatam utilitatem fere semper deprehendere possimus, Ill. Eques Hamilton insignem regionum vulcaniis cineribus coopertarum uti Campaniae felicis, Aetnae radicum, fertilitatem admirans, dicebat, subterraneos ignes magnum esse naturae aratrum exhaustis terris nova salia, novam ubertatem adferens.

Sed longum requiritur tempus antequam lavae arabili et fructifera terra cooperiantur. Vidi lavam quae Dionysii tyranni tempore ex furenti Aetna defluens Carthaginienses copias a Messana Syracusas petentes morata est, quae igitur fere 22. saeculorum antiquitatem habet, multis in locis omnino nudam et nullibi fructiferam, nisi ubi hominum industria advecta est humus. Non enim sola aeris actione mollescunt, uti quidam perhibent, marmore duriores et aquis imperviae lavae; sed pulveri ventis deposito minimi innascuntur fungi, dein musci, gramina, tandemque frutices, quorum omnium radicibus frondibusque putrescentibus sensim efformatur humus.

Quot igitur requisita sunt saecula, ut alterna formarentur humi et lavarum strata quae ad Aetnae et Vesuvii radices tanto numero sibi mutuo alternatim superposita deprehenduntur? Sed maiorem etiam antiquitatem indicant isti vulcanii montes quorum indubitata vestigia tot in locis demonstrantur, quorumque tamen ne minima quidem mentio antiquissimis in historiis invenitur. Hi tamen antiquissimi et nunc extincti vulcanii *tertiariis* montibus recentiores sunt, cum per ipsos tertiarios erupisse eosque eruptionibus suis subvertisse videantur. Ipsi vero *tertiarii, secundariis, primariisque* iuniores sunt; cum eorum ruinis fragmentisque constructi fuerint. De *secundariis* autem iam vidimus, quantum tempus ad eorum regularem lentamque sub mari formationem requisitum fuisse videatur. Quid igitur de *primariorum* antiquitate cogitabimus, qui ceteros omnes praecessise apparent? Quid de inauditis nec intelligendis vicissitudinibus, quas in tellure nostra tantae mutationes indicant?

Obstupescit animus, nec quidquam pronuntiare audet. Fatendum tamen est, potuisse Deum Omnipotentem propter sapientissimos sed nobis incognitos fines terrarum orbem ita condere, ut antiquitatem vera maiorem nobis ostendat; sicuti senis statua rugas exhibet, quas tamen ipsa statua non contraxit, vel sicut nova nonnumquam extruuntur aedificia, quae antiquissimas imitantur ruinas.

Ne tamen credas, Ornat. Adol., philosophos qui magnam antiquitatem Universo tribuunt Sacrorum Codicum auctoritati adversari. Docti enim Sacrarum Litterarum interpretes Mosis narrationem non esse ad verbum intelligendam, multisque modis cum maiori Telluris antiquitate conciliari posse probaverunt. Sicque philosophicis disputationibus vastum liberumque campum reliquerunt. Haec igitur nostra, si neminem offenderit, animisque vestris non iniucundum pabulum obtulerit, contentus discedam.

Dixi.

TRANSLATION INTO ENGLISH OF *DE MONTIUM ORIGINE*

A Question

When I stroll in my father's gardens by the most beautiful shore of our Lake, the attractive view towards the east always fills me with wonder and delight. Particularly when the sun has already set at the angle of the level ground, but still lets fall shimmering rays, refracted by the mists, on the high tops of the mountains, and dyes the eternal snows of the Alps with fiery color, I halt spellbound by the amazing sight, quite unable to turn my eyes away.

You must not believe, however, most distinguished Sir, that my attention is wholly gripped by the beauty of the colors. Meanwhile I reflect how high those mountains are, how far and broad their extent; and when the enthusiasm for philosophy turns my mind towards examining the causes of things, I yearn to know the origin and formation of those enormous masses. And so, I eagerly open Burnet [1], Whiston [2], and particularly the most illustrious Buffon [3]. But I find in their systems clever fictions rather than a faithful interpretation of nature, and I immediately fall back into a doubt, though a doubt preferable to ignorance.

I have indeed heard that there has originated in Italy an unusual theory which attributes the origin of all mountains to subterranean fires; and that it has been recently adopted by men of distinction and supported with fresh observations. Since these are not so well known, I beg you, most honorable Sir, to share with me and with this select gathering what you have heard about these things on your travels, and what also by investigating the nature of things you have found out to be true.

Oration

I too, most honorable Candidate of Philosophy, frequently linger over the marvellous and amazing sight of our Alps, plunged into profound thoughts. Nor have the ingenious systems of the authors satisfied me any more than you.

Though I myself have traversed so many mountains, and crossed the Alps by five different passes, and often have wandered both in the lowest valleys and on the tops of their slopes, even so I would hardly dare to bring forward conjectures which in my view would be more certain than the conjectures of these eminent men. In those labors I have rather unlearned errors than learned the truth.

I do not want to take the time of this learned gathering and of you, honorable youth, with the well-known faults of well-known systems or with my own pointless conjectures. I will therefore communicate some more certain observations both concerning mountains in general and volcanoes, and at the same time I will explain and weigh the Italian theory, which is scarcely known on this side of the Alps. But neither the refinements of the Latin language, to which my inspiration would not lay claim,

nor an orator's style should be expected in a scientific treatise. I will set out my conclusions in as well-ordered a way and as clearly and briefly as I can.

I do not know whether it is simply a fiction of the human brain, or the memory of some huge conflagration or of ancient volcanoes; but it is certain that a universal conflagration of the world, preceding a universal flood, is recorded in the stories of ancient peoples. And this seems to have been the reason why Zoroaster, Pythagoras and other ancient philosophers have derived the origin of the universe from fire.

Among the modern authors, some who have written cosmogonies have argued that the primitive state, not indeed of the whole universe, but at least of our earth was fiery; for example, Descartes, Leibniz, Buffon. Others, leaving aside the question of the primitive state, have supposed a perpetually burning fire, called by them the "central fire", in the bowels of the earth: so Kircher, and M. de Mairan [4], whose recent death was such a loss to science.

It was however, so far as I know, a famous Venetian called Lazzaro Moro, who first applied these subterranean fires to the explanation of the origin of the mountains. So that you may understand his system better, most honorable young man, and may reach a more certain judgment about it, I will explain to you briefly the general structure and arrangement of the mountains, as both others' and my own observations have shown them to be.

Our land is surrounded on all sides by great and unbroken mountainous tracts, which in French we call *des chaînes de montagnes* such as *les Cordillières, les Alpes, les Pyrénées.* Each of these tracts is made up of several ranges or lines of mountains, mutually parallel, but in nature and height quite different.

The middle and highest range is filled with mountains called *Primary,* for example in our Alps, Saint-Gothard, Mont-Blanc, Mont-Cenis. Their matter is practically everywhere an unusual kind of stone, called by the moderns *granite,* because it is apparently made of little grains. The Greeks called it *pyrrhopoecilon,* on the grounds that it was mottled with fiery color; the Romans *syenites,* because it was quarried near the town of Syene in the (Egyptian) Thebaid. We call it *serpentine* because of its serpent-like spots; the French *granit,* since for them *serpentine* is applied to another kind of stone.[5]

The material of Primary mountains is evidently not always made up of grains, but also of flakes and wisps; but these components, regardless of their composition, always show a characteristic aspect within the same mass, and distinct colors. They are always angular and yet precisely and mutually interlocked without any visible cement. They always resist acids, and by the most intense oven fire tests they are turned, not into lime, but into a porous glass.

Some types have such a compact structure that they display unusual resistance to the universal ravages of climate and time. For this reason they were always employed by the ancient Egyptians in all their major works, in which they proudly sought everlastingness. They found a very handsome type of this stone, fiery red

in color, in the upper Thebaid. Their success may be judged, honorable young man, when I tell you that obelisks of Syenite, transported to Rome by the magnificence of the emperors and with extraordinary efforts, were carved with figures, and yet some of these outlines even today are just as clear as if they had recently been cut with an extremely sharp blade.[6]

Granite mountains deserve special attention for the fact that they are not, like other mountains, marked by parallel and regular strata. They are heaped up in enormous masses, with fissures irregularly scattered here and there.

They are also noticeable for the fact that mountains of different type are seen overlapping their bases, while they themselves never rest upon other mountains. Quite large blocks of granite were transported here and there and may even be found in our Lake, but real mountains of this stone resting on a different bed you will not find anywhere. Moreover, no extraneous bodies, nor parts either of plants or of animals of any sort, are found in the depths of granite mountains or in actual masses of this rock. These observations show that these mountains and rocks are older than the others, and prove that the name of *Primary* has been rightly and properly given to them, both because of their antiquity and because of their hardness and height.

Secondary mountains are less hard, less ancient, and less high, and are usually of limestone, for example our Salève and the Jura, or of shale. They normally overlie the bases of Primary mountains and are arranged in parallel order among themselves. They are characterized by strata, which, unless broken or disturbed by earthquakes, preserve parallelism both among themselves and with the horizon. In all these, the observant eye detects traces of plant life, or the actual fossils of animals, especially marine animals; and with such great frequency in certain limestone mountains that many naturalists consider that shells and corals are the primary and only source of calcareous matter.[7]

Tertiary mountains, lower than Primary and Secondary, are made up of their ruins and fragments, sometimes free and unconsolidated, sometimes cemented together into hard rocks. They also show parallel strata and the buried fossils of animals and plants.

Therefore in all the extent of mountains which may be examined, the *Primary* mountains make up the central and highest crest; the *Secondary,* close to them, are lower; the Tertiary slope down by stages to the level of the plains. The plains and the valleys are filled with mingled fragments of every type of mountain, carried down and rounded by the force of water. This may be seen on the banks of the Lake, of the Rhône, of the Arve, and in the hills close to our City.[8]

Smaller mountain chains like the Apennines and the Jura are without Primary mountains and are made up only of Secondary and Tertiary mountains.

Now, honorable young man, with the general differences of mountains understood, you will more easily grasp the system of the famous Italian. The

ingenious author supposes that the earth, freshly created, was perfectly spherical and covered with fresh water, and that its floor was of the same rock as that making up the matter of the Primary mountains. But on the third day of Creation — for he intends to adapt his theory to the narrative of Moses — huge fires kindled inside the earth thrust up the Primary mountains which earlier formed the floor of the sea. Since they were raised, not in one piece, but broken and split, through gaps and fissures surging fires erupted, which hurled into the air ashes and all kinds of materials. Those materials, falling back into the sea, spontaneously arranged themselves in horizontal strata, and formed the stratified layers of the Secondary mountains. Salts were also poured out by the fire, and so the sea became salty, and the Divine power created fishes to live in it. But soon, under the new mountains still covered by the sea, new fires broke out, which carried the mountains aloft along with shells and fishes. So the continents and islands were born from the waters, and the sea became restricted to its regular boundaries. Meanwhile, above the exposed rocks, soil was formed and plants grew. But new fire-spewing apertures were also opened, which belched out ashes and formed new mountains filled with buried organisms. So it may be understood why Secondary and Tertiary mountains are characterized by strata and contain extraneous bodies. On the other hand, the Primary mountains, created by a unique act of the Supreme Will at the same time as the universe, present no indications of successive formation. This is Moro's imaginative tale, but a tale that has been found weak in many respects.

The first objection is that, in very many Secondary mountains, sea shells, fishes, and other extraneous bodies are found, not torn and buried at random as if by some violent motion, but arranged in communities and set in their natural position, exactly as they occur in their native places; and so these mountains, both in this and other respects, show clear proofs of a slow and regular deposition requiring long ages of time. It has also been noted that, except for the old and recent volcanoes, all the other mountains contain no glassy products or materials changed by fire, while the Primary mountains are made up of granites, and the Secondary of shale and limestone rocks, which have suffered nothing from fire.

This objection, which is drawn from the limestone that makes up many Secondary mountains, was apparently contradicted by a striking observation.

The first author of this observation is the most noble knight (Sir William) Hamilton, noted for his devotion to antiquity and extraordinary interest in nature no less than for his high birth and his office as British Ambassador.

All students of nature know the region near Naples called by the inhabitants *Solfatara,* which by undeniable signs reveals the mouth (or, as it is called, *crater*) of an ancient volcano. It is a small plain, surrounded by a continuous circular hill, of molten stones named *lavas,* and by pumice. This place in antiquity was known as the *Forum Vulcani,* perhaps because of the flames which in those days still burned.

Now there are no longer flames, but extremely hot vapors which rise from the fissures and apertures of the lava, sometimes with freshwater steam, sometimes with acidic and choking steam exactly resembling the smoke of burning sulfur. All volcanoes emit such vapors. I myself, when standing on the highest edge of Vesuvius, was almost choked by a very thick cloud of sulfur smoke which suddenly erupted. I was surrounded by a black fog, hardly able to tell what direction I should take in order to save my life by flight. I have also felt a similar fume on top of Mount Etna, but less choking. Since Etna has more or less three times the height of Vesuvius, as I detected by barometric observation, the heavier particles of acid rise only slowly and then fall back. But Sir William Hamilton noted and pointed out to me not only at the Solfatara but also in other places that these sulfurous fumes, when coming in contact with pieces of pumice or lava, slowly corrode them, soften them, and turn the black and hard lava into the whitest earth.

Indeed that white material, dried by the heat of the sun, changes into a white powder much resembling lime. Washed away by the rains, and deposited on lower grounds, it eventually hardens, assumes different hues, and by its veins and colors falsely resembles marbles and alabasters.

This gave rise to the hypothesis that in the past the materials which, according to the fiction of Moro, had been hurled up by fire, could have lost the signs of combustion and been changed into lime. But it was found by more careful investigation that the earth in question, the powder and the masses formed from it, were not lime, but clays, a type of earth very different from lime.

This observation of the distinguished Knight which has shown the conversion of lava into earths by acidic fumes, although quite new and of great importance,[9] cannot however lend any support to the feeble system of Moro; and it must still be regarded as certain that *Secondary* mountains underwent their processes of deposition under the sea itself, by the slow and successive accumulation of earth, shells and plants.

It is to Neptune then that the creation of the *Secondary* mountains and of the Tertiary mountains which are so like them must be assigned. A new effort has however been made to reassign the Primary mountains to Vulcan. The distinguished researcher and fellow-countryman of Lazzaro Moro — still, as I hope flourishing at Venice — Giovanni Arduino, has shown that the Euganean hills near Padua were once volcanic, and are entirely the product of fire. He has discovered unusual types of lavas, which are quite similar to certain granites. He considers as probable therefore that the *Primary* mountains, once formed within the bosom of the earth by subterranean fires, were eventually uplifted to the surface.

Moreover, he argues that the layers of the *Primary* mountains on all sides are inclined toward the plain, as if the mountains, in being thrust up from the bowels of the earth, in their upward movement lifted the rocky crust of the earth. In fact, layers of Primary mountains so inclined do occur in several places. But they are found

inclined also in the opposite direction, in such number that this observation cannot supply a solid support for the system.

So far as the similarity is concerned between lavas and granites, it is neither universal nor can it sustain a careful comparison; and oven fire tests affect these lavas differently from real granites.

Moreover, granites never show those round bubbles, which scientists call fire pores, of the type we so often find in glass and in all similar materials and in lavas themselves.[10]

For this reason, in rejecting completely the Italian system, I would not at all attribute the formation of granite and of the Primary mountains to fire, and I would rather think of them as having been formed under water, since they are replete with and indeed made up of crystals of the type normally growing in water but not in fire. But in such an obscure matter, I beg you not to ask for a proof and the process or the time of such formation.

Nevertheless it is certain that subterranean fires exercise a great influence not only on the genesis of the shapes of mountains but also in changing their shapes. Although no traces of them have so far been found either in the vicinity of our City or in the nearby mountains, in all parts of the world unquestionable proofs are daily found of ancient volcanoes, and vast regions and very many whole islands are entirely volcanic.

At times also mixed remains are found both of sea and fire. Thus on the Isle of Ischia, once called *Pythecusae,* and in the hills near Rome, I have seen strata of pumice and lava, alternating with strata of marine stones and shells, so that these hills seemed to be formed by the alternate action of fire and water. In the Vicenzian Alps, in the midst of limestone mountains, both in ancient times and modern, fires have broken out, and molten lava flowed through the fractures of limestone strata.[11]

And since in all the works of the Deity we may more or less always detect some advantage meant for ourselves, Sir William Hamilton, admiring the extraordinary fertility of regions covered with volcanic ashes, as of Campania felice and the foot of Etna, used to say that subterranean fires were Nature's mighty plough, bringing to exhausted soils new salts and new fertility.[12]

But a long time is required before lavas are covered with arable and fertile earth. I have seen lava which in the days of Dionysius the tyrant flowed from erupting Etna and hampered the Carthaginian forces as they marched for Syracuse from Messina, lava therefore about 2200 years old. In many places it was entirely bare and nowhere fertile, except where soil had been brought in by human effort. For it is not only by the action of air, as some maintain, that lavas becomes friable though they are harder than marble and impervious to water. But when dust has been deposited by the winds, tiny molds grow on them, then mosses, grasses, at long last bushes, and by the decay of the roots and leaves of all these gradually soil is formed.

How many centuries are needed then for the formation of the alternate strata of soil and lavas which at the feet of Etna and Vesuvius are seen superimposed on each other in such number? But an even greater antiquity is shown by those volcanoes whose undoubted traces are observed in so many places, and yet of which not even the least mention is found in the most ancient histories. Yet, these most ancient and now extinct volcanoes are more recent that the *Tertiary* mountains, since they seem to have erupted through the Tertiary mountains themselves and by their eruptions to have dislocated them. The *Tertiary* mountains themselves indeed are younger than the *Secondary* mountains and *Primary* mountains, since they are made up of their debris and fragments. In the case of the *Secondary* mountains, we have already seen how much time seems to have been needed for their regular, slow formation under the sea. What therefore shall we think of the antiquity of the *Primary* mountains, which clearly preceded all the others? What about the extraordinary and unintelligible successive phases which such great changes show in our earth?

The mind is dumbfounded and speechless. Yet one must admit it is possible that Almighty God, for reasons most wise yet unknown to us, could have created the world in such a way as to show us an age greater than the real one, just as the statue of an old man displays wrinkles which were not made by the statue itself, or as sometimes new buildings are constructed in imitation of the oldest ruins.

Do not believe however, honorable young man, that the philosophers who assign great antiquity to the universe are opposed to the authority of the Sacred Books. Scripture scholars have shown that Moses' narrative is not to be understood literally, and may be reconciled in many ways with a greater antiquity of the earth, and so they have left to scientific enquiries a vast and free field. If this enquiry of mine causes no offense, and offers all of you pleasing food for thought, I will depart satisfied.

The End

Discussion

Format and Content

The student's question begins with a description of his unbounded admiration of the scenery of the Alps as seen from the garden of his father. This is the spectacular view from the villa Lullin at Genthod, near Geneva, where Saussure spent many summers of his youth. The student then raises the question of the origin and formation of the mountains in general and the Alps in particular after having allegedly read the theories of the earth or systems of Thomas Burnet (1681), William Whiston (1696), and Buffon (1749) and found them to be clever fictions rather than faithful interpretations of nature. This is a judgement that a student could hardly have the

capability of reaching on authors with whom Saussure himself was quite familiar. Then the question of the student turns to a new theory which attributes the origin of all mountains to subterranean fires, namely volcanoes, requesting the professor to give an opinion based on his travels and experience. This new theory is the vulcanistic system of Antonio Lazzaro Moro published in Venezia in 1740 (Fig. 1), translated into German in 1751, and apparently little known in Geneva at the time. Saussure must have learned about it during his trip to Italy, most probably from Sir William Hamilton at Napoli from the surroundings of which Moro drew some of his major arguments (eruption of Monte Nuovo in 1538).

In summary, the student must have been coached quite extensively by Saussure himself so that his question would be far-reaching enough to warrant a lengthy reply from the professor.

The Strict Neptunian Answer in De Montium Origine

In his answer Saussure discussed mountains (a designation also used for the rocks themselves as well as for the reliefs they build) using the threefold classification of Primary, Secondary, and Tertiary, a terminology tacitly agreed upon in his time and whose precise origin is debatable. It may perhaps be attributed to J. G. Lehmann (1756) and to G. Arduino (1759, 1760, see J. J. Ferber, 1773). It was used by the numerous students of A. G. Werner as early as 1775 and formalized by him in 1787 when he finally put in writing his Neptunian theory. This classification was also used by P. S. Pallas for the Urals in 1777. It should be pointed out that the terms of Primary (Primitive), Secondary, and Tertiary do not correspond with the modern definitions of Paleozoic, Mesozoic, and Cenozoic except in the case of the Alps. The threefold classification, if it pertained to rocks of different ages according to the mountain ranges considered, expressed a major structural pattern that naturalists of the 18th century had observed in all mountain ranges and used for descriptive and genetic purposes.

In *De Montium Origine,* Saussure described the three types of mountains as follows:

Primary Mountains consist of granite heaped up in enormous masses with fissures irregularly scattered through them. Primary rocks form the highest mountains of the chains, they are the oldest known and devoid of fossils.

Secondary Mountains, lower than Primary Mountains, usually consist of shales and limestones with marine fossils overlying the margins of the Primary Mountains. They are characterized by distinct beds in horizontal position.

Tertiary Mountains, lower than Primary and Secondary Mountains, consist of unconsolidated or consolidated debris such as sandstones and conglomerates originating from the destruction of the older mountains. They also form horizontal beds and contain marine to freshwater fossils.

DE

CROSTACEI

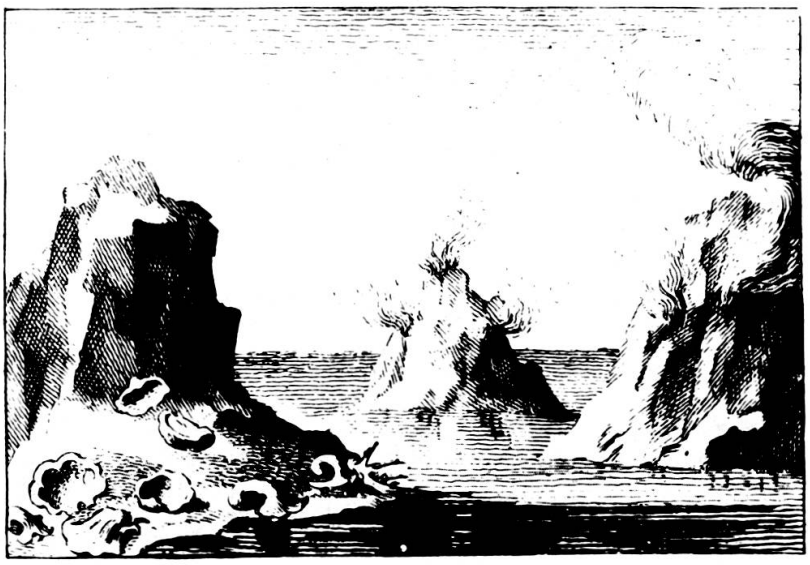
E DEGLI ALTRI

MARINI CORPI

Che ſi truovano ſu' monti

LIBRI DUE

DI ANTON-LAZZARO MORO.



VENEZIA

APPRESSO STEFANO MONTI

CON LICENZA DE' SUPERIORI, E PRIVILEGIO.

Si vende preſſo Angiolo Geremia in Merceria, all'inſegna della Minerva.

MDCCXL.

FIG. 1.

Title page of Moro's theory of the earth (1740).

It is easy to recognize in Saussure's description the typical Neptunian system developed at the time by the school of A. G. Werner in Freiberg. It was based on the geology of Saxony and only known at the time by hearsay. In short, this system assumed that the earth, devoid of an internal fire, was originally covered by a universal ocean which decreased in time and in temperature by successive phases. The Primary Mountains were produced by massive chemical precipitation of granite and associated rocks in deep water over an unknown substratum. Upon lowering of the universal ocean, the Secondary Mountains (called Floetz) containing marine fossils were deposited by a combination of chemical and mechanical processes. Finally, the Tertiary Mountains (called alluvial deposits) derived from erosion of the older ones were detrital sediments laid down just before the ocean drained to its present level. Finally, volcanic rocks were formed. The Neptunian theory assumed that oceanic waters had gradually disappeared by decomposition into gases to form the terrestrial atmosphere. It also stated that all rocks were deposited horizontally and that any observed tilting of the beds should be of local significance and attributed to effects of crystallization or collapse processes.

In essence, the Neptunian system is devoid of any dynamic process capable of uplifting and folding strata. Its demise was to be at the hands of Werner's own students who in traveling around the world found geological features in complete disagreement with the rigid and static system of their master.

Refutation of Moro's Vulcanistic Theory

As pointed out by Saussure in his answer, Moro's theory of 1740 says that Secondary and Tertiary mountains were formed by volcanic action implying the existence of a central fire in the earth. A central fire had been assumed by many other authors such as R. Descartes (1664); A. Kircher (1665); G. W. Leibniz (1749); and J.-J. d'Ortous de Mairan (1719, 1765); Buffon (1749); and P. S. Pallas (1777). Saussure himself considered the principle of internal heat as hypothetical and gratuitous. In that respect he remained Wernerian. He believed that the heat of the earth came from the general and constant source of the sun, that the temperature decreased with depth in the crust, and that the center of the earth would be its coldest place (*Voyages dans les Alpes...*, vol. 3, 1796, § 1412 and 1413).

In spite of his own ideas, Saussure's summary of Moro's system is perfectly correct. In the light of his previous presentation of the formation of mountains according to a strict Neptunian approach, the refutation is so to speak automatically implied. One of the best objections presented by Saussure is the occurrence of many types of fossils in the limestones of the Secondary mountains forming undisturbed natural communities that provide an undisputable proof of the slow and gradual deposition of these limestones on the sea floor. This situation would not occur if these fossils and their enclosing sediments resulted from the violent resedimentation

of exploded volcanic products. This is one of the rare instances in which Saussure wrote on paleoecology and the mode of preservation of fossils, a subject which was not among his major preoccupations.

It was clear to Saussure that the limestones of the Secondary mountains displayed no traces whatsoever of the action of fire. However, he related the fact that this objection to Moro's ideas had apparently been contradicted recently by an observation made at the Solfatara first by Sir William Hamilton and shown to him subsequently when they were together in the field. This observation showed that acidic sulfurous fumes coming in contact with pumice or lava alter them so deeply that they are changed into a white earth. Upon drying in the sun, this material changes into a white powder resembling lime which when redeposited by rainwater in lower places hardens and displays different colors and veins resembling marbles and alabasters.

The original text of the discovery made by Hamilton and contained in a letter to the Royal Society of London, dated Naples, March 5, 1771 says:

> A great part of the cone of that ancient volcano (the Solfatara) has been (and is being) calcined by the hot vapours. Pumice calcined seems to be the chief ingredient, of which several specimens (as I suppose) of variegated uniform marble are composed, and the beautiful variegations in them may have probably been occasioned by the mineral vapours. As these specimens are now sent to the Royal Society, you will see that these variegations are exactly of the same pattern and colours as are met in many marbles and flowered alabasters; and I cannot help thinking that they are marble and alabaster in its infant state. What a proof we have here of the great changes the earth we inhabit is subject to! ... I have seen half of a large piece of lava perfectly calcined, whilst the other half out of reach of the vapours has been untouched; and in some pieces the center seems to be already converted into true marble.

Hamilton also stated that at another place of the Solfatara the strata of erupted matter contain large masses of bitumen in which its former state of fluidity is very visible. He thought that this observation was the first of its kind ever made and proved that pumice was produced from bitumen, evidently by a gradual process since the crystalline vitrifications of the bitumen remained in the same state in the perfect pumice as in the bitumen. He added: "If you consider the process I have traced from bitumen to pumice, and from pumice to marble, you will think with me that it is difficult to determine the primitive state of the many wonderful productions we see in nature".

Although Hamilton enjoyed some reputation as an amateur student of volcanoes, many of his conclusions were often less than scientifically rigorous. Such is the case here. Indeed finding masses of bitumen among volcanic products would have demonstrated one of the most disputed questions of the time, namely the origin of volcanoes attributed either to the combustion of buried plant (coal) and animal

bituminous materials or to the fermentation of masses of pyrite. Unfortunately this was really not the case. What Hamilton called bitumen with a fluidal texture, is most certainly pitch-black obsidian with crystallites which naturally by degassing evolves into pumice.

This assumed wholesale calcination of pumice and lava into marbles by acidic sulfurous fumes gave rise, according to Saussure, to a hypothesis supposed to be in favor of Moro's ideas, namely that materials projected by the subterranean fires could have lost all traces of their volcanic origin by having been changed into limestones and marbles. But, Saussure added that the argument became invalid upon further studies which showed that the white earth and the indurated masses it formed consisted of clay and not of lime.

The processes really taking place at the Solfatara are fairly complex (Pichler, 1970). Most of the overheated steam (130 to 165°C) of the vents is of vadose origin, the rest of the steam with CO_2 and H_2S is of deep origin coming from the cooling magma. Around most of the vents, native sulfur is deposited by oxidation of the H_2S in contact with the oxygen of the air. Quite often, the oxidation proceeds further with the formation of SO_2 which, reacting with water forms sulfuric acid which decomposes the volcanic rocks, leaching their bases which are replaced by a variety of sulfates, while the silica of the silicates forms a very porous residue of opal. This whitish alteration product which may reach 90% opal contains locally large quantities of sulfates, among which is alunite, which was commercially mined in the past. The alteration product covers the bottom and the external slopes of the Solfatara crater (Colli leucogei = white hills) and is locally called "Bianchetto".

Refutation of Arduino's Volcanic Origin of Primary Mountains

At the end of his reply Saussure discussed a renewed attempt to assign a volcanic origin to Primary mountains. It was made by G. Arduino in an account dated 1759 and in two letters to A. Vallisnieri in 1760 (republished by Ferber, 1773). After a study of the mountains around Padova, Verona, and Vicenza, and particularly the Colli Euganei, Arduino had found unsual types of lavas which he thought resembled granites. He thus came to the conclusion that Primary mountains consisted of two types of rocks. First, the oldest ones, devoid of fossils, formed by vitreous and micaceous materials, namely granites and porphyries produced by the melting action of subterranean fires at depth which were subsequently uplifted to the surface. Second, various types of schistose rocks with very few fossils, rich in mineral veins, and formed by the combination of fire and water. Arduino also argued that the schistose rocks adjacent to the granites were inclined toward the adjacent plains, demonstrating the vertical uplift.

Saussure stated that a similarity between volcanic lavas and granites was unacceptable and that schistose layers of the Primary mountains also dip in the opposite

direction, and that this situation did not support the volcanic origin and uplifting of the granites. Again, in this refutation Saussure remained strictly Wernerian in his interpretation of granites as chemical precipitates at the bottom of the universal ocean, although begging his audience not to ask for the proof, the process or the time of such a mode of formation. He did not mention his own idea of uplifting granite "beds" by an explosion of elastic fluids (not volcanoes). His statement on the inclination of the schistose transition rocks remained out of precise geographic context because had he mentioned his observation of such a fact in the Alps he would have revealed his own theory which he obviously did not want to do.

Saussure's Concluding Remarks

Toward the end of his reply Saussure talked about the work of the Deity in which "we may more or less always detect some advantage meant for ourselves". This is the first written statement of the deistic attitude of Saussure which we had suspected for many years (Carozzi, 1987, 1989). It resembles the attitude of James Hutton (1788) who, in his theory of the earth, thought that the composition, dissolution, and restoration of land upon the globe was for the benefit of humankind.

Saussure terminated his reply by statements concerning the immense duration of geologic time during which the great changes corresponding to the formation of the various types of mountains took place in an "extraordinary and unintelligible" succession of phases. However, he left open the possibility that God may have created the world to look older than it really is. He added that the great antiquity of the world was not opposed to the Scriptures and if one did not take Moses' narrative literally then a vast field of endeavor was left open for science. In Saussure's unpublished and published record there is no mention of Creation or of any other religious preoccupations. "Nature" is always designated as the responsible agent. The above references to the Deity, Almighty God, the possible deceptively old age of the world, and Moses' narrative may be statements preempting any possible criticisms of Saussure — at the time Rector of the Academy — from the "Vénérable Compagnie des Pasteurs", the powerful protestant church of Geneva.

Relation between the Strict Neptunian Geology of De Montium Origine *and Saussure's own Geological Observations and Concepts*

The four volumes of Saussure's *Voyages dans les Alpes...* published between 1779 and 1796 consist in many cases of composite assemblages of observations and interpretations (not necessarily updated from one trip to another) borrowed from numerous itineraries, repeated many times during various years. Hence Saussure's published record cannot be used as a reliable source to document the chronology of the successive and important changes in his outlook on the structure of the Alps

in particular and of his theory of the earth in general. The only reliable sources are Saussure's field notes.

Indeed, the study of his field notebooks (Carozzi, 1989) preserved in the Saussure Archives in Geneva provides not only a complete chronological account of his numerous trips, but gives also interspersed short memos and comments scribbled during his trips or at home between trips. He called these documents "Idées détachées" (loose thoughts). They are mostly spontaneous synthetical ideas resulting from freshly observed facts and sometimes philosophical considerations. All these ideas pertain to his theory of the earth which circumstances and ill health prevented him from writing in full at the end of his life. They represent therefore critical markers of his evolving thinking.

For instance, it becomes clear that between 1758 and 1772 he gradually came to the conclusion that the various types of granites of Mont-Blanc, a major part of the Primary Mountains of the Alps, had originally been deposited by chemical precipitation at the bottom of the deep universal ocean in horizontal beds, and that, after their complete induration, they were upturned together with associated gneisses and micaschists into a vertical position by the effect of an unknown upheaval (bouleversement). The observation of these so-called "vertical beds of granite" was perhaps Saussure's major mistake. In spite of his excellent knowledge of high elevation weathering processes, he mistook the numerous systems of vertical or highly inclined tectonic joints for bedding planes. This error of interpretation (with respect to modern thinking) was to remain a key concept of his subsequent synthesis of the Alps. During his entire life he looked at granites in other mountain ranges and kept convincing himself that granite was bedded and in vertical position in the highest ranges.

In 1774, after climbing the Cramont, a high summit immediately to the south of Mont-Blanc, affording a spectacular view of the rest of the Alps, he wrote his first essay on the formation of the Alps in his notebook. We find it again there in final form in 1778, and eventually in the *Voyages dans les Alpes...*, vol. 2, 1786, § 919. Saussure's concept of the formation of the Alps in 1774 can be summarized as follows. Granites and other primitive rocks were deposited first in the lowering universal ocean as stratified chemical precipitates overlaid by transition rocks. The shales and fossiliferous marine limestones of the Secondary Mountains were deposited over the transition rocks as a result of biological and mechanical processes. Finally, Tertiary Mountains consisting of sandstones and conglomerates, originating from the erosion of the older mountains, were deposited by mechanical processes.

Saussure assumed that the deposition of this entire sequence of sediments required an immense length of time. About 100,000 years ago, after all sediments from primitive to tertiary had been completely indurated, fire or the explosion of other elastic fluids enclosed in caves within the earth's interior broke open the crust, uplifting and upturning the central primitive rocks into a vertical position while the

more external part, consisting of the transition, secondary and tertiary rocks was folded, tilted and pushed aside, resting on the primitive rocks in a very steeply inclined position which decreases gradually away toward the margins of the Alps until a horizontal attitude is reached. The remaining waters of the universal ocean were then engulfed in a gigantic flood (débâcle) or general retreat which drained toward open and empty cavities generated by the explosion of the elastic fluids and located along the margins of the Alps. The flow of these debris-laden turbid waters transported for long distances the large blocks of primitive rocks (the Pleistocene glacial erratics of modern geology) that occur scattered in the plains on both sides of the Alps.

Although Saussure later changed his mind in favor of horizontal thrusts to explain the structure of the Alps (Carozzi, 1989), in 1774 he felt he had reached an extremely important conclusion. He had in fact broken the Wernerian tradition by combining the lowering of the universal ocean with a pre-plutonian concept of vertical movements occurring in a single orogenic event produced by internal causes such as fire or the explosion of elastic fluids. In his field notebooks, he characterized the process as violent and almost instantaneous comparable to an extraordinary seismic shock. He was clearly more in favor of the explosion of elastic fluids — in fact a popular concept at the time — however mysterious these fluids might be, than the action of fire of which he said he found no traces in the Alps. Saussure thus did not refer to volcanism. He mentioned that mountains produced by volcanoes have little resemblance to the regular chains of the Alps.

In *De Montium Origine,* which is also dated 1774, we find a strict Neptunian interpretation of mountain building with no reference whatsoever to his ideas mentioned in his notebooks. Saussure was apparently well aware of the importance of his new and revolutionary ideas, but did not share them with his students: he gave them, with the help of the classical dialogic form, "the party-line", the dogma prevalent at the time. There seems nothing unusual in this if we compare Saussure with a professor teaching a modern subject matter in which he is doing advanced research. He too would give his students merely the state of the art without mentioning the results of his own unpublished revolutionary research. In short, if the apparent coaching of the student in asking a well-documented and pertinent question is combined with the fact that Saussure's reply does not reveal his latest ideas, then *De Montium Origine* can be interpreted as a real class exercise in a philosophy course, a piece of Socratic irony behind which his own views are masked.

ENDNOTES FOR ENGLISH TRANSLATION

1. Thomas Burnet, in his diluvialistic theory of the earth (1681), believed that all elements were organized radially in order of decreasing density. Starting from the center, the earth was surrounded by water, oily substances, and air. However,

the oily substances became gradually charged with earthy particles originating from the cleansing of the air, and a crust was formed capable of sustaining living things. A perpetual spring reigned at the time upon earth, but the wickedness of humankind led to Divine intervention, a catastrophe during which the sun's rays dried up the crust and split it open. Some parts of the crust collapsed and allowed the central abyss of waters to burst forth and flood the inhabited land. This Deluge left the earth's surface in ruins which are the islands in the oceans and the mountains and plains on land.

2. William Whiston assumed in his own diluvialist theory (1696) that the earth was originally a comet during the time of chaos until God decided to make it a planet. From that time until the Flood, the earth revolved around the sun in a perfectly circular orbit with its axis perpendicular to the plane of the ecliptic; hence there were no seasons and no daily rotation. The Flood which stopped this situation was produced by a comet guided by God. The head of the comet broke the crust of the earth by its impact and caused the waters of the abyss to burst out while its tail, passing over the equator, generated a gigantic rain, both contributing to the Deluge. The oblique impact of the comet on November 18, 2349 BC displaced the earth's axis, changed the circular orbit into an elliptical one, and gave to the earth is rotational movement. It was from the chaotic sediments of the Flood that the various stratified formations and their fossils found on continents were deposited.

3. In Buffon's first theory of the earth (1749), planet earth had been detached from the sun by the impact of a comet. It went through a phase of fusion followed by an episode of cooling during which water vapors in the atmosphere condensed into a universal ocean which covered a thin vitreous crust. Ocean movements reworked the scoriaceous crust into sands that later became granites, sandstones, and clays to which subsequent organic activity added limestones. All these rocks were deposited horizontally and marine currents carved them into mountains, while the sea level was lowered for reasons not explained.

In his second theory of the earth of 1778 (*Epoques de la Nature*), Buffon stated that the phase of fusion was followed by an episode of cooling during which the high granitic mountains were generated. The first irregularities of the earth's surface and the formation of internal caverns dated from the period of fusion. Upon further cooling, water vapors in the atmosphere condensed into the universal ocean which covered the entire earth except the top of the highest granitic mountains. Waters then began to recede and disappear into caverns of the earth's interior. Decomposed granite gave rise to clays and sands, and abundant marine fauna generated most limestones. All mountains younger than granite were shaped by submarine currents. Plants from exposed areas decomposed into coal and pyrite providing the fuel for volcanoes.

4. Jean-Jacques d'Ortous de Mairan (1678-1771), French physicist who searched for proofs of an internal and permanent source of heat for the earth which would be the cause of volcanoes.

5. The statement that "we [the common people] call granite serpentine because of its serpent-like spots" is rather misleading. Saussure knew better (see *Voyages dans les Alpes...*, vol. 1, 1779, § 107 to 111 for a full discussion of serpentine and § 130 to 148 for granite). He did not attempt to educate his students in that respect. Serpentine is the name given to compact or granular rocks, with a greasy or silky luster, a soapy touch and a conchoidal fracture, uniformly light to dark green or with mottled shades of green. Serpentines are concentrations of secondary minerals derived from the alteration of magnesium-bearing silicates (especially olivines) found as distinct bodies both in igneous and metamorphic rocks. Translucent varieties are used as ornamental stones as a substitute for jade.

In Geneva, at the time of Saussure, granite was often improperly called serpentine by quarrymen, in the same manner as massive to granular limestones which could take a high polish and be used as ornamental stones were called granites, a confusion which regrettably still continues today in popular language.

6. This rock is a coarse-grained porphyritic granite with red orthoclase quarried under the name of "monumental granite" at Aswan. It was originally called syenite by Pliny after Syene, the ancient name of Aswan, but is not a syenite in the modern petrographic sense.

7. A concept strongly promoted by Buffon.

8. These are Pleistocene interglacial outwash gravels (alluvion ancienne) forming the hills around Geneva, and recent alluvials of the Rhône and the Arve, and gravels on the beaches of Lake Geneva.

9. Saussure in his letter to Hamilton, dated December 12, 1774 and published in 1776, stressed that the latter had been the first (see his letter to the Royal Society of 1771) to observe at the Solfatara the change by acidic and sulfurous fumes of volcanic rocks to clays, whereas this discovery had been attributed by G. Arduino to J. J. Ferber (1773) who visited Naples in 1772 when Hamilton was on a trip to England.

In reality, as reported above, Hamilton described only the change of volcanic rocks to marble and not to clays. It remains unclear why Saussure wanted to save Hamilton's reputation. Perhaps it was a gesture toward the British nobility which greatly impressed him during his "grand tour" of 1768.

10. Fire pores are the vesicles formed by degassing of lavas and leading to pumiceous materials.

11. This is an observation of G. Arduino probably communicated orally to Saussure when they met.

12. These comments were published in Saussure's letter to Hamilton (1776). At the end of this letter, Saussure announced another one to come on the volcanoes of the State of Venice, his crossing of the Alps through Tyrol, and on columnar basalt. It was never published.

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