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THE ORIGINAL CHEMICAL ANALYSIS OF DOLOMITE BY NICOLAS-THÉODORE DE SAUSSURE (1792): A LABORATORY ERROR AND ITS HISTORICAL CONSEQUENCES

BY

Albert V. CAROZZI* and Donald H. ZENGER**

This paper is dedicated to the memory of Déodat de Dolomieu on the 200th anniversary of the discovery of dolomite.

ABSTRACT

An annotated translation into English is given here of N.-T. de Saussure's article (1792) in which he named *dolomie* the "weakly effervescent limestone rock" discovered by D. de Dolomieu the previous year. His faulty chemical analysis showed that dolomite was a double carbonate of calcium and aluminum. The history of the ensuing controversy about the chemical composition and terminology of dolomite, lasting 16 years, is discussed in detail, until the final demonstration, in 1808, that the rock called dolomite and the well-crystallized double carbonate of calcium and magnesium mineral or magnesian spar, whose correct chemical composition was known since 1779, were the same substance. The role played by Dolomieu himself in this controversy, as well as the history of another mineral substance dedicated to him, are reviewed.

RÉSUMÉ

Une traduction critique en anglais est présentée de l'article par N.-T. de Saussure (1792) dans lequel il nomme *dolomie* "la roche calcaire faiblement effervescente" découverte par D. de Dolomieu l'année précédente. Son analyse chimique erronée montre que la dolomie serait un carbonate double de chaux et d'alumine. L'histoire de la controverse concernant la composition chimique et la terminologie de la dolomie qui en a été la conséquence pendant 16 ans, est discutée en détail jusqu'à la démonstration définitive en 1808 que la roche dolomie et le carbonate double de calcium et de magnésium bien cristallisé ou spath magnésien et dont la composition chimique correcte était connue depuis 1779, étaient la même substance minérale. Le rôle joué par Dolomieu lui-même dans cette controverse, ainsi que l'histoire d'une autre substance minérale qui lui a été dédiée, sont passés en revue.

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INTRODUCTION

On the occasion of the celebration of the 200th anniversary of Dolomieu's discovery of dolomite, we are presenting a translation into English with comments of N.-T. de Saussure's article (1792) in which he proposed to call the "weakly effervescent limestone rock" *dolomie*. He described its external characters, as well as the action of fire, water, and acids on dolomite, presented its chemical analysis, and discussed at great length its phosphorescence.

Written at the time when Lavoisier's revolutionary work was being published, the chemical terminology of Saussure's paper combined pre-Lavoisier and Lavoisier concepts. We have maintained the flavor of 18th-century chemistry language by using the original terminology with modern equivalents explained in square brackets or in footnotes.

Saussure's paper is of great historical interest today because it contains the original chemical analysis of the rock dolomite from which he concluded that it was a combination of calcareous earth, clay, and fixed air (CO_2) — in modern terms a double carbonate of calcium and aluminum — and that its slow solubility in acids was due to the difficulties these encountered in attacking this combination of calcareous earth and clay.

The history of the controversy about the chemical composition and the terminology of dolomite which arose from this faulty chemical analysis follows the translation. Although S. Tennant discovered the error in 1799 and gave the correct composition of the rock dolomite, and while N.-T. de Saussure acknowledged his mistake in 1800, the original error was repeated in all major textbooks of mineralogy for 16 years. Only in 1808, D.L.G. Karsten formally stated that the rock called dolomite and magnesian spar, whose correct chemical composition was known since 1779, were the same substance.

The role played by Dolomieu in this controversy is discussed, particularly his suggestion of naming the rock after H.-B. de Saussure, had he made the chemical analysis himself. Little-known data are provided on another poorly-defined substance, also dedicated to Dolomieu.

TRANSLATION INTO ENGLISH OF *ANALYSE DE LA DOLOMIE*
BY MR. DE SAUSSURE, THE SON

The slow and nearly imperceptible effervescence which certain calcareous rocks yield on testing with acid is a fact which Commander de Dolomieu has just brought to the attention of mineralogists in a very interesting letter to Mr. Picot de la Peyrouse (*Journal de Physique*, 1791)¹.

1. Dolomieu, D. de (1791). Sur un genre de pierres calcaires très peu effervescentes avec les acides et phosphorescentes par la collision. *Journal de Physique*, 39, 3-10. See also English translation under same title by A.V. Carozzi and Donald H. Zenger, *Journal of Geological Education*, 1981, 29, 4-10.

FIG. 1

Only extant notes of N.-T. de Saussure on the chemical analyses of the Marmo Gr. antiq. (*Marmo greco antiquo*) on pages 1, 2, and 4 (repeated twice), and of the Dolomite of Tyrol on page 3; samples sent by Dolomieu on October 31, 1791 (BPU, Archives Saussure, No. 142).

1

Pier

Analyse du marmo l^y antiq.

100 gr. ont été mis en diss. dans acide mur.

ces 100 gr. ont été précipités

par alkali minéral carb.

le précipité traité par la potasse

caustique cette potasse sursaturée

turée et précipité par point

d'argille. L'argille servait elle

restée en comb. avec la terre

calcaire

Les terres précipitées par

les alkalis ont pesé 74. il y a

donc eu une perte de 26 grains

mais l'alkali caustique a la propriété d'enlever

le g^r acide carb. à la Magnésie ces 26

gr. étoient un déchet.

2

mis 50 gr. en acide vitros

et exposé à une forte chaleur

36
18
3,5
57,5
13
44,25

Dissous dans l'eau, elle avoit

un goût amer

100 grains

creuset de platine pesé avec

sulph. de chaux et de Magnésie

 $3\frac{1}{2}$ onces + $57\frac{1}{2}$ grains

Sulphate de Magnésie dissous

à une chaleur rouge pesé 44,5

Sulphate de Magnésie pesé 25

13 donne des sels = 69,5

216 creuset de platine pesé 3 onces

+ 276 gr. ou $3\frac{1}{2}$ + 276 gr. + 60244,5
60

3

analyse de la Dolomie du Tyrol

mis 50 gr. en acide vitros liq

fait rougir

creuset de platine avec sulph. de

Ch. et de Mag $3\frac{1}{2}$ + 56 gr.

sulph. Magnésie pesé 45 gr.

il est réduit à $3\frac{1}{2}$ + 13 gr.

Sulphate de chaux pesé 43 gr.

Sulphate de Magnésie pesé 25

4

Recommence l'analyse de

Marm. l^y antiq.

100 gr. ont perdus par leur dissolut

dans l'acide mur. $45\frac{1}{2}$ gr.ces $45\frac{1}{2}$ gr. ont pesé

ils ont été précipités par le carb. de soude

ces 100 gr. ont donné un précipité pesant

114 gr. qui a été bien lavé

Mr. Fleuriau de Bellevue², on returning from his trip in the Tirol, was kind enough to give me a few pieces of this material, until now little known, and Mr. de Dolomieu, to whom I then wrote, sent me some superb specimens of its principal types.

In all respects, this rock deserves a special name, because that of slightly effervescent calcareous rock is vague and inappropriate. It is befitting to derive its name from that of the famous naturalist who introduced it to us.

Mr. de Dolomieu has recognized this rock in some monuments in ancient Rome and in stream beds heading in the Alps. He has seen it in place in the mountains of the Tyrol. Linnaeus³ who is familiar with dolomite informs us that it can be found at Roedberg in Norway. He gave it the appropriate name of *Marmor tardum* in defining it in this manner: *Marmor particulis subimpalpabilibus album diaphanum. Hoc simile quartzo, durum, distinctum quad cum aqua forti non, nisi post aliquot minuta & fero, effervescens.* (White, translucent marble consisting of very finely subdivided particles. This is similar to quartz, it is hard and is distinguished by the fact that it does not effervesce with acid unless after a few minutes and relatively late.)

I must call to your attention that it is not at all necessary to confuse it with pearl spar⁴, or with manganesian spar [rhodochrosite], nor with certain sparry iron ores [siderite] which do not have, with the exception of slow effervescence, any relationship with the rock with which we are concerned here.

External Characteristics of Dolomite

The external characteristics of dolomite are insufficiently distinct and variable to be able to alone allow its recognition.[162, original pagination] I have not yet observed it in a definite crystalline form⁵; the salt-like [crystalline] grain that it very frequently possesses apparently indicates that it has this disposition, its texture is more compact than that of most known calcareous rocks and moreover, is similar to that of nearly all their varieties; it is capable of taking a beautiful polish.

2. Louis-Benjamin de Fleuriau de Bellevue (1761-1852) was a wealthy nobleman from La Rochelle interested in mineralogy (flexible sandstones) and crystallography. He went to Italy during the Revolution and upon returning to France he became involved in applied geology. Through his publications, he became a corresponding member of the Académie des Sciences of Paris. In 1801, he began a short and unsuccessful political career after which he returned to scientific activities. He was president of the Société d'Agriculture de la Rochelle and founder of the Société des Sciences Naturelles and of the Muséum of La Rochelle. For many of his unpublished papers, see A.V. Carozzi (1990). *Histoire des Sciences de la Terre entre 1790 et 1815 vue à travers les documents inédits de la Société de Physique et d'Histoire naturelle de Genève. Trois grands protagonistes: Marc-Auguste Pictet, Guillaume-Antoine Deluc et Jean Tollot, S.P.H.N., Mémoires*, 45, 2, 411 p.

3. Linnaeus, Carl von (1768). *Systema Naturae, per Regna Tria Naturae secundum classes, ordines, genera, species, cum characteribus et differentiis*..., 12th improved edition, Holmiae, Impensis Laurentii Salvii, 3 vols, vol. 3, 41.

4. Pearl spar is saddle-shaped secondary dolomite occurring often in cavities of porous dolomites. It was called at the time manganesian spar.

5. Saussure was examining rock samples, not individual crystals.

The hardness of this rock is greater than that of ordinary marbles; it sometimes even yields sparks with the tinder box, although it does not possess an odor of siliceous earth [chert]. A tempered steel blade scratches it with difficulty; forged iron and brass leave their metallic streaks on it. Its fracture appears to have a tendency toward a conchoidal form.

The color of dolomite ranges through the following varieties: milk white, light brown, reddish yellow, gray and reddish. These colors, which are never very dark, depend on the different states of iron, which always occurs in small amounts in this rock. The surface does not noticeably change color on exposure to open air and light.

It has a higher specific gravity than all the marbles tested by Mr. Brisson⁶; the average specific gravity of four different varieties is 2.850.

The dolomite that I have tested in various ways of which I will talk shortly, comes from the Tyrol. Its specific gravity is 2.862; it has the salt-like [crystalline] texture, and the white color of the statuary Carrara marble; it is phosphorescent upon impact, but without producing sparks with the tinder-box.

Its phosphorescence on impact, as observed by de Dolomieu, is not an essential character of dolomite nor is it limited to only some of its varieties because Mr. Fortis⁷ and Mr. de Laumont⁸ have found that this property is possessed by several very effervescent marbles.

I will not at all attempt to reconsider the principal cause of this phenomenon or to research whether the phosphorescence on impact is due to the alteration of the rock itself, or to an electric effect, or to incandescence that can occur to the rubbed parts by the movement that excites them; but, I would note that this phosphorescence does not depend as much on hardness as on the texture of the substance, which by its nature is prone to produce the phenomenon of which we are concerned. So, I have seen several very hard dolomites which were not at all phosphorescent on impact, whereas others much softer were endowed to a very high degree with this quality. Chemical analysis did not reveal any difference between these varieties, but the first ones had a very fine and very compact texture, the second ones a coarser and more porous texture. It is thus

6. Mathurin Jacques Brisson (1723-1806), professor of physics at the Collège de Navarre, École Centrale and Lycée Bonaparte. Member of the Académie des Sciences of Paris and of the Institut de France. He published books on natural history and chemical history of mineral substances. See *Pesanteur spécifique des corps*, Paris, Imprimerie Royale, 1787, 453 p.

7. Giovanni Battista, called Alberto Fortis (1741-1803), Augustine Abbot and Italian geologist. He lived first in Rome, then traveled extensively and ended his career as librarian at Bologna. He was a member of the Academia of Padova. He published many papers on the geology of Italy and countries around the Adriatic Sea. See in particular *Mémoires pour servir à l'histoire naturelle et principalement à l'oryctographie de l'Italie, et des pays adjacens*, Paris, J.J. Fuchs, 1802, 2 vols.

8. François-Pierre-Nicolas Gillet de Laumont (1747-1834). Officer in the French army, then General of the Corps des Mines and member of the Académie des Sciences of Paris, he published numerous papers on mineralogy applied to industry. See in particular, *Sur quelques propriétés des pierres calcaires, relativement à leur effervescence et leur phosphorescence*. *Journal de Physique*, 1792, 40, 97-101. R.J. Haüy named the zeolite laumontite after him.

possible that essentially all dolomites have the potential to be phosphorescent but that all are not, because their texture is not always suitable to produce this effect.[163]

I have made some tests that tend to support this view; several pieces of marble, whether white or colored, which have been coated with phosphoric acid obtained from deliquescent phosphoric glass [melted metaphosphoric acid which is a vitreous matter soluble in water] do not show any sign of phosphorescence by rubbing after having been dried in a crucible under mild heat whereas several specimens of ordinary chalk subjected to the same fire and acid as the marbles in the preceding experiments emit large flashes of light when struck with a feather. This phosphorescent chalk stripped of the thin glossy layer that had formed on its surface, still retained its phosphorescent property whereas externally it appeared to be of the same nature as perfectly pure chalk.

The intensity of the light caused by striking must be, all things being equal, directly related, in the bodies from which it is emitted, to their resistance to striking, or to the fact that their constituents show more roughness. Could not one assume that in the chalk whose texture is more porous the calcareous phosphate had sufficient space to crystallize so as to produce much roughness whereas in the compact and tight marble, internal crystallization could not occur? Calcium phosphate crystallizes very easily by the dry method. On decomposing some gypsum with some phosphoric glass [metaphosphoric acid], I have obtained, with a very great heat of fusion a greenish-white salt consisting of superposed prismatic blades often striated, and sharply truncated at their extremities; this salt is very phosphorescent by rubbing with a feather.

Effect of Fire on Dolomite

Dolomite on the end of a glass tube exposed to the flame of a blowpipe is not completely fused but it vitrifies at the surface without changing color. This rock crushed, placed in a platinum crucible, has been subjected to very great fire without undergoing melting; however its particles became slightly agglutinated, its whiteness was not altered, it lost 0.462th of its weight. A yellow dolomite, which yielded sparks with the tinder box, and which did not have a crystalline texture was exposed to the same fire; it whitened and lost 0.472th of its weight. The white to semi-transparent pearl spar was altered by the same procedure to a black scoria, lost 0.455th of its weight, and the statuary white Carrara marble 0.415th. These tests show that dolomite is not composed only of oxygenated calcareous earth because it becomes slightly vitrified by the blowpipe. One sees also that it is one of the calcareous rocks that experiences the greatest loss by the action of fire although it appears less effervescent with nitrous acid. Dolomite dissolves with [164] effervescence by the dry method in borax and in mineral alkali [sodium carbonate]; it forms white transparent glasses with these salts. I placed gradually 100 grains [one grain equals .053 grams] of dolomite in molten nitre [potassium nitrate]; it produced neither light nor explosion, and the nitre that contained it did not change color after one digestion of an hour in red heat. It would thus appear

that this rock does not contain manganese and that the other metallic calxes⁹ that may be part of its composition are in very small amount.

Effect of Water and Acids on Dolomite

Two hundred grains of dolomite were placed in two pounds of boiling distilled water for two hours without leaching a noticeable amount of material. This water was reduced to about one-eighth of its volume. In that state the nitrous solutions of mercury and silver hardly reacted with it; barotic [baritic, L. B. Guyton de Morveau used the term barote for barite] and saccharin acid [oxalic acid] solutions produced slight precipitates.

Dolomite that has been pulverized and sifted through a silk screen is hardly soluble in cold distilled vinegar. It took nine hours to make it dissolve in that acid, heated to 60° on the Réaumur thermometer, and in a quantity 48 times as much as the dolomite. It released a few clay floccules which eventually redissolved. The solution was condensed by spontaneous evaporation, thickening to a syrup without showing other signs of crystallization than some silky and delicate tufts that grew on the sides of the beaker that contained it. I did not notice any well-developed crystallization when it was later exposed to mild heat.

A mass of dolomite produces an effervescence scarcely noticeable to the naked eye when moistened with a drop of nitrous acid. This effervescence becomes more evident when it is pulverized. It completely dissolved in this cold acid. The same amount of nitrous acid that dissolves rhombic calcite in three minutes takes six hours to dissolve pulverized dolomite. This solution is transparent and colorless. When this is done in a very dilute solution of nitrous acid, the solution becomes turbid by a small quantity of ferruginous clay. It crystallizes by the combination of evaporation and cooling. If the latter is rapid and the evaporation very advanced, the entire solution congeals into a

9. The French term is "chaux métallique," the English "metallic calx," a term used in pre-Lavoisier chemistry to designate earths of metals deprived of their phlogiston by several procedures (fire, acids, detonation with nitre) and consequently of their metallic properties. Lavoisier explicitly stated (1789, vol. 1, p. 84) that the terms "chaux métalliques" or metallic calxes were obsolete and should be replaced by the terms metallic oxides. For further discussion see A. Lavoisier (1789). *Traité Élémentaire de Chimie, présenté dans un ordre nouveau et d'après les découvertes modernes*, Paris, Cuchet, 3 vols.; A. Lavoisier (1796). *Elements of chemistry, in a new systematic order containing all the modern discoveries by M. Lavoisier, translated from the French by Robert Kerr*, Edinburgh, William Creech, 590 p. (also Dover Reprint, 1985); P.J. Macquer (1771). *A Dictionary of Chemistry containing the theory and practice of that science... translated from the French anonymous Dictionnaire de Chymie of 1766 by James Keir*, London, T. Cadell and P. Elmsly, 2 vols. For an extremely useful review of chemical terminology of the 18th century, see Jon Eklund (1975). *The Incomplete Chymist, being an essay on the eighteenth-century chemist in his laboratory, with a dictionary of obsolete chemical terms of the period*, Smithsonian Studies in History and Technology, Number 33, Smithsonian Institution Press, Washington, D.C., 49 p.

semi-transparent mass consisting of tufts or of sheaves constricted in their middle and with more or less slender threads. If evaporation and cooling are carefully controlled, transparent and loose blades are formed that appear to be composed of needles for the most part oriented parallel to one another. These needles as seen with the magnifying glass appear to be four-faced, very compressed prisms which terminate either by a beveled surface or by dihedral apices.[165] This solution crystallizes more rapidly and more easily than that of the perfectly pure calcareous rock. If the latter is combined with a small amount of clay, it shows the same crystallization effects with nitrous acid.

Dissolution and effervescence of dolomite in marine acid [hydrochloric acid] are still slower than in nitrous acid; it crystallizes as pyramids with four faces of which the apices are commonly truncated. The crystallization is better developed when dolomite contains less iron. The salt, as well as that produced with nitrous acid, is deliquescent.

Vitriolic acid [sulfuric acid] rapidly dissolves dolomite with a violent effervescence similar to that which it produces with ordinary calcite. White and shapeless gypsum is deposited during the dissolution; the remaining solution, filtered and evaporated to dryness deposits silky gypsum. The water which helped to wash and purify these gypsum residues, precipitates through its evaporation a significant deposit, which when again washed and purified with distilled water, produces a solution whose concentration provides some well defined crystals of alum. One hundred grains of dolomite yielded 118 grains of dried gypsum and 6.2 grains of clay precipitated by the volatile alkali [caustic ammonia] as crystals of alum.

It is important to identify the gas emitted from dolomite in its dissolution by acid. Accordingly, I have treated 100 grains of this rock with vitriolic acid [sulfuric acid] in the pneumatic trough¹⁰ and I obtained 55 cubic inches of air consisting of nothing other than carbonic gas [carbon dioxide, also fixed air]. It clouds the lime water, is absorbed by water, by the caustic alkalies [caustic lyes or potassium hydroxide] which become effervescent.

Distillation of calcined dolomite with vitriolic acid at low heat does not produce any gas at all, if one ignores a small amount of sulphurous acid, which comes from the vitriolic acid itself; thus this rock does not contain any spathic acid [old name for fluoric or hydrochloric acid] at all.

I attempted to determine the amount of water that dolomite contains by comparing the loss that it suffered by fire to that which is yielded by its solution by nitrous acid in a distilling flask of which the long and straight neck is closed by a glass stopper that is not sufficiently tight for the emitted gas to be unable to escape. One hundred grains of this rock have lost by this procedure 46.4 grains, the same quantity of rhombohedral calcite

10. An apparatus developed during the 18th century, from John Mayow (1641-1679), Stephen Hales (1677-1761), to Antoine Lavoisier (1743-1794). The trough was a large vat full of mercury in which inverted bottles full of water could be supported. Glass tubes conducted the gases from the vessels in which they were generated outside the trough to the inverted bottles in the trough where the gases were trapped and held (Eklund, *op. cit.*, p. 35).

39.4 grains, the statuary white Carrara marble 38 grains, and finally pearl spar which dissolves still more slowly in acids than dolomite, 40 grains. These substances lost by fire in the same order 46.2; 44; 42.5; 45.5.

We can conclude from these tests that dolomite is one [166] of the calcareous substances that seems to contain the least water; but we will not conclude that it does not contain any at all, because it is impossible to suppose that newly formed fixed air [carbon dioxide] does not carry with it a part of the water combined with the nitrous acid, or even a small amount of nitrous acid.

Action of Water and Some Acids on Calcined Dolomite

Calcined dolomite on being heated combines with water to produce the same effects as quicklime and forms lime water that becomes turbid by contact with carbonic acid gas [carbon dioxide]. About three-quarters of the weight of this rock is soluble in water. The insoluble quarter is composed of nothing else than calcareous earth, clay, and iron.

The calcareous part of the calcined dolomite dissolves as rapidly in acids as ordinary quicklime. The solution is made turbid by a certain amount of clay which remains undissolved depending on the nature or the concentration of the acid used. One can extract the clay from the calcined dolomite by digesting the latter in gently heated distilled vinegar. By this method I have obtained from 54 grains of this calcined rock, eight grains of clay combined with a small quantity of iron. When the dolomite has not been calcined, one cannot succeed in separating the clay from the calcareous earth by this method.

After having quenched 54 grains of dolomite in water, I have exposed it in a dry spot for four months. At the end of this time, it had reached a weight of 44 grains, it then dissolved promptly and with violent effervescence in nitrous, marine [hydrochloric], and acetic acids. The solution was always turbid because of the clay it contained. Calcined dolomite placed under a bell jar filled with carbonic acid gas [carbon dioxide] that overlies mercury did not absorb one atom of the acid. This calcined rock, but quenched in water, becomes saturated with carbonic acid gas under the same circumstances. The quicklime, just as observed by Mr. Bucquet¹¹, produces analogous effects, and only becomes saturated with fixed air [carbon dioxide] because of the quantity of water that it contains.

11. Jean Baptiste Michel Bucquet (1746-1780), physician, professor of chemistry at the École de Médecine in Paris, member of the Académie des Sciences of Paris. He wrote numerous papers on chemistry, see in particular *Introduction à l'étude des corps naturels tirés du règne minéral*, Paris, J.T. Hérissant, 1771, 2 vols.

Analysis of Dolomite

I have attempted to determine by ordinary analytical methods the amounts of different substances contained by dolomite. I will note on this occasion that the long process of gemstone analysis, as described by T. Bergmann, could be much shortened after the preliminary separation of gypsiferous earth, by separating the dissolution of the other earths by aqua regia, in as many portions as there are elements to identify in the rock that one examines, in order afterwards to identify separately one element in each [167] portion and to estimate by the rules of proportion the result that one would have had if one had operated on the whole substance subjected to analysis.

By following this method, one avoids several troublesome procedures, which, moreover, are detrimental to the precision of the work, and one shortens the time in making all the filtrations, dryings and washings simultaneously.

Thus, after having dissolved 400 grains of dolomite in aqua regia, I divided the solution into four portions which can be done immediately when one has beakers of known capacities.

I formed some calcareous saccharate [oxalate of calcium] with saccharin acid [oxalic acid] in the first portion and following the estimation given by T. Bergmann, the weight of this precipitate indicated that 100 grains of dolomite contain 44.29 of calcareous earth.

A solution of vitriolic tartar [potassium sulfate] produced no precipitate in the second portion, which proves that this rock contains no heavy earth at all.

Concentrated caustic volatile alkali [caustic ammonia] precipitated clay and iron in the third portion, the weight of these two substances being 6.70 grains [analysis below gives 6.60 grains].

Iron was precipitated by phlogisticated alkali [potassium ferrocyanide] from the fourth portion. Its weight reduced according to the proportion discovered through the preliminary experiment as advised by R. Kirwan is 0.74.

The difference between the weight of the rock analyzed and that of the sum of its constituents that I have just obtained, including fixed air, would have yielded the amount of magnesium contained in this dolomite; but as it is more precise to give specifically each distinct chemical product, I have taken the solution in which I had precipitated clay and iron, and I separated from it: (1) calcareous earth with saccharin acid [oxalic acid], (2) magnesium alone with mineral alkali [sodium carbonate]. The weight of this last earth is equivalent to 1.4 grains. Thus, 100 grains of dolomite contain:

lime	44.29	grains
clay	5.86	"
magnesium	1.4	"
iron	0.74	"
carbonic acid	46.1	"
Total	98.39	"
Loss	1.61	
	100.00	

[168] I investigated if the clay contained by the samples I analyzed was at all accidental and I discovered that all the other types that I possess also contain at least as large an amount.

One has seen that dolomite is different in some of its characters from the nature of ordinary calcareous rocks and that it approximates them in all respects after its calcination and its saturation in carbonic acid and water; one has recognized that the gas that saturates it prior to its calcination is entirely carbonic acid, and that the earth that dominates it is calcareous. I believed at first that the absence of water in dolomite was the reason for its density and its slow solubility in acids; but, a more thorough examination has convinced me that this reason itself was only secondary. Indeed, one cannot imagine why some calcareous rocks much older than the dolomites and which contain shell debris, would not present the same difficulty in dissolving, if this effect in them resulted from a simple desiccation. The experiment proves, moreover, that water is a necessary intermediary for calcareous earth to combine with carbonic acid and that this combination only operates because of the amount of water that is involved here. It appears that clay is essential to dolomite; it is thus possible that the clay serves here as an intermediary and that dolomite is nothing more than the combination of calcareous earth and clay with fixed air, and that its slow solubility is due primarily to the difficulty with which acids attack the combination of calcareous earth and clay¹².

These considerations prompted me to investigate whether this particular combination, which results from the precipitation of lime water by clay, was susceptible to combine with carbonic acid. To this end, I diluted 25 grains of clay precipitated from alum with caustic volatile alkali [caustic ammonia] in 5 pounds of water and I mixed them with 7 pounds of lime water. It would be very difficult to determine the saturation point of this compound, which always varies in proportion to the fineness of the clay. The washed, purified and filtered precipitate was exposed to open air for a month; it absorbed carbonic gas from the atmosphere and it dissolved in nitrous and marine [hydrochloric] acids with a slower effervescence than that of pure calcareous earth.

I would be inclined to believe that the combination of clay and calcareous earth contains a small but essential quantity of water, the amount of which could not be exactly determined by our experiments. Before having been calcined, this compound is soluble in slightly warm acetic acid and in cold nitrous and marine [hydrochloric] acids; it is no longer the same after calcination: one of the acids, in particular vinegar, dissolves only the calcareous earth and leaves the clay unaffected, [169] probably because fire has destroyed this combination by removing its essential water.

12. All the samples of dolomite analyzed by N.-T. de Saussure allegedly contained mainly calcareous earth, an appreciable amount of clay (alumina), little magnesia, essentially no water, and a high amount of carbonic acid. Consequently, for him, dolomite was a combination of calcareous earth, clay and fixed air (CO₂), in modern terms a double carbonate of calcium and aluminum, and its slow solubility in acids was due to the difficulty they encountered in attacking this combination of calcareous earth and clay. Following Saussure's analysis, the new rock, which he called dolomite, became known in French as *chaux carbonatée aluminifère*. See our comments below on the ensuing controversy.

Thus, the result of these experiments is that dolomite is nothing more but a compound of carbonic acid with clay and calcareous earth, that calcined dolomite does not have the property of becoming again slowly effervescent by exposure to open air, because the clay is no longer chemically combined with the calcareous earth and because this compound cannot be formed when one of the two earths is dissolved in a solution. Dolomite is found to be very effervescent after its calcination and its combination with carbonic acid to be in the same case as certain very effervescent calcareous-argillaceous marls, in which calcareous earth and clay are not chemically combined.

*Examination of the Phosphorescence Shown by Some
Calcareous Rocks on Contact with a Hot Body*

The light emitted from certain minerals by contact with a hot body is a characteristic that has been ignored too much up to the present and that perhaps could, by means of tests, inform us about their constituent parts.

Pulverized dolomite produces a very beautiful light when placed on an iron scoop heated to the stage below glowing. This effect occurs without a noticeable odor. With regard to intensity and duration, the light from dolomite is nearly equal to that which is emitted by chalk under the same circumstances; but it is totally different with respect to color. Phosphorescence of chalk as well as that of fluorite is a bluish white; that of dolomite is a very striking orangish red.

Dolomite that has yielded this effect once, when submitted again to the test of a scoop heated almost to redness, only offers signs of a hardly detectable white light after having been exposed to sunlight for several hours. This rock loses none of its phosphorescence at all by boiling with distilled water.

I believe that three general kinds of phosphorescence can be distinguished in calcareous rocks contacted by a hot body.

The first appears to be the effect of combustion in open air of sulfur or of liver of sulfur¹³ that the rock contains. This effect can be distinguished from the following ones because it is the only one that requires outside air.

The second appears to be the result of a simple absorption of light; it occurs every time that the substance is exposed to light. All compounds more or less share this property; it is very striking in certain diamonds and in some substances prepared for this purpose by calcination.[170]

The third occurs only once in the same compound but without external air, as in water, in a vacuum, and in the very interior of the rock, such is the phosphorescence of fluorite and of several calcareous rocks.

13. "Foie de soufre," in English "liver of sulfur," is produced by a reaction of potassium carbonate and sulfur upon heating. It is not a true compound but a metastable mixture of potassium polysulfides and potassium sulfates that tends to decompose eventually into the sulfate. At the time, alkaline sulfides were called indiscriminately liver of sulfur too.

A good deal of attention has been paid to the first two types of phosphorescence and little to none at all to the third. I have done some experiments on this subject and it appeared to me that when the phosphorescence of the calcareous rocks is due neither to combustion occurring in open air nor to the effect of light to which the rock has been previously exposed, it is due to the light that is emitted from the acid that it contains during the process of its combination with the flammable principle [phlogiston] by the dry method or with more or less deoxygenated metallic calx that is united with it and that is in excess by the wet process.

All calcareous rocks characterized by this last type of phosphorescence of which I have spoken produce signs of the presence of sulfuric or marine [hydrochloric] acid when treated properly with distilled water. Because this latter acid appears to be the cause of the phosphorescence of a great number of calcareous rocks and because it does not form liver of sulfur with charcoal, I have elected to prove that which I have just proposed.

According to all the books on the elements of chemistry, the combination of calcareous earth and marine acid produces light when in contact with a red-hot iron, but apparently when these two substances are perfectly pure this effect never occurs.

Very pure, aerated calcareous earth, such that one obtains at the surface of lime water by the precipitation in open air or that of certain perfectly white and transparent Iceland spar, does not yield any noticeable light when in contact with a red-hot iron.

I have dissolved up to saturation perfectly transparent and non-phosphorescent calcite in ordinary distilled muriatic acid. This filtered solution, by evaporation in an evaporating dish, has left a white and friable residue, which was not in the least more phosphorescent than the residue left by the solution of muriatic acid with excess of pure calcareous earth. Subjected to fire up to vitrification, the residues have not yielded any light under the same circumstances.

Very pure aerated calcareous earth put in the first residue when it is molten produces a strong effervescence but without phosphorescence. If in place of adding pure calcareous earth, one adds half-oxygenated calcareous earth charged with iron [ferroan calcite] a very beautiful phosphorescence is noted, although the material added did not possess the property at all. If the mixture is removed on purpose from the crucible and before [171] the combination is completed, it is still, after cooling, phosphorescent upon contact with a red-hot iron.

The residue from evaporation of the muriatic acid solution made with an excess of half-oxygenated calcareous earth charged with iron always produces, with the help of heat, a very beautiful phosphorescence.

Finally, if one sprinkles iron filings in molten calcium muriate, the muriatic acid calcines this metal and combines with it in producing a bluish-white light that rises several inches above the mixture. This light transudes across the crucible, which is itself engulfed in a bluish gaseous haze. Bubbles are emitted from the mixture which on bursting in air give a dazzling white. The black manganesian calcareous earth in molten calcium muriate emits a white smoke that colors the charcoal flame red.

The light produced is always inversely proportional to the oxygenation state of the metal.

Based on these tests, it appears that the hydrochloric acid produces in its compounds, by the dry method, effects analogous to those that Mr. Westrumb¹⁴ obtained when this acid is in the oxygenated, gaseous state.

Homborg's phosphorous [boric acid] or calcium muriate that results from decomposition of sal ammoniac [ammonium chloride] by quicklime, apparently owes the beautiful light that it yields in large part only by heat, to the volatile alkali, that the oxygenated muriatic acid gas can also accomplish.

Phosphorescence of Fluorite

If we now examine the phosphorescence of fluorite, we see how the phenomenon and all the effects that are associated with it must be the result of the chemical composition of the substance that produces it. The phosphorescence of fluorites is directly related to the intensity of their colors and following Rome de l'Isle (volume 2 of his "Crystallography")¹⁵, those that are completely white and transparent do not possess this property at all. Therefore, phosphorescence is not an essential characteristic of fluorite.

Most colored fluorites owe their coloration to the presence of iron, as C. W. Scheele has proved (Stockholm Memoir, 1771)¹⁶. Thus, fluorites become more phosphorescent with increasing iron content or because this iron is in a less oxygenated state. Fluorite loses its coloration together with its phosphorescent property; this fact seems to indicate a higher oxygenated state of the metallic calx it contains. As long as the phenomenon lasts it produces a sparkling and an extraordinary decrepitation; it does not seem to depend [172] solely on the water of crystallization and the unequal dilation of its surfaces because, for a given degree of heat, this sparkling increases with the vividness of the phosphorescence and ceases with it. I have subjected four ounces of green and semi-transparent fluorite from St. Gothard to phosphorescence in a well-

14. Reference too vague to be traced. Johann Friedrich Westrumb (1751-1819), was pharmacist at Hameln, Germany, where he became also Bergkommissar and Senator. He wrote books and articles on chemistry, industrial applications of chemistry, and analytical techniques in physics.

15. J.-B. L. Romé de l'Isle (1783). *Cristallographie ou Description des formes propres à tous les corps du règne minéral dans l'état de combinaison saline, pierreuse ou métallique*, 2ème édition, Paris, Imprimerie de Monsieur, 4 vols. See vol. 2, p. 7.

16. C.W. Scheele. Undersökning om fluss-spat och dess syra. *Kongl. Vetenskaps Akademiens Handlingar*, 1771, 120-138, also in *Abhandl. der K. Schwedischen Akademie der Wissenschaften* aus dem Schwedischen übersetzt von A.G. Kästner, 1771, 33, 122-139; also in *Suite d'expériences par lesquelles M. Scheele a découvert les principes des spaths fluors et leurs propriétés, tirées des Mémoires de l'Académie Royale des Sciences de Suède pour l'année 1771, ouvrage traduit de l'Anglois. Introduction aux Observations sur la Physique...*, 1772, 2, 473-481. See also *The Chemical essays of Charles-William Scheele. Translated from the Transactions of the Academy of sciences at Stockholm with additions* (by Thomas Beddoes), London, J. Murray, 1786, 406 p. Essay I. On fluor mineral and its acid, 1771 (1-26), Essay II. On fluor mineral, 1771 (27-36).

sealed crucible. These four ounces have decreased to 1.25 grains. A repeat experiment produced the same result.

Because fluorite loses its phosphorescence and part of its weight by calcination it seems certain that there is a change in its composition; I have convinced myself of the nature of this change by the following experiments.

I have boiled 200 grains of non-calcined fluorite in one pound of distilled water for several hours. The filtered solution concentrated by evaporation showed no sign of the presence of iron by the infusion of some drops of calcium prussite [calcium ferricyanide]. Silver solution and saccharin acid [oxalic acid] have not noticeably clouded it. The residue resulting from evaporation was white, weighed one-half grain, and was not at all deliquescent; it appeared to be non-decomposed fluorite.

The same operation was repeated on a similar amount of fluorite calcined up to vitrification in a platinum crucible. Its solution, concentrated by evaporation stained calcium prussite blue, silver solution made a very apparent precipitate with it, saccharin acid clouded it, and the residue of this solution evaporated to dryness weighed 1.5 grains; it was deliquescent, took on a brownish color on exposure to air and it seemed to be in large part calcium muriate [chloride] charged with considerable iron. This salt is, therefore, the result of a change in composition that effects fluorite by the application of fire. C. W. Scheele (*Journal de Physique*, 1783)¹⁷ proved that fluorite always contains a considerable quantity of marine acid that becomes noticeable in the decomposition of this spar by vitriolic acid.

Spathic acid [hydrofluoric acid] has greater affinity for lime by the wet method than does marine acid (*Nova Acta Upsal.* vol II)¹⁸. It is therefore evident that when fluorite is formed, spathic acid absorbed all the calcareous earth to the exclusion of marine acid that combines here neither with this earth nor with iron but with fluorite itself, for one finds neither calcium muriate nor iron muriate in this spar.

T. Bergmann and C. W. Scheele demonstrated by the dry method that the affinities of spathic acid change and that marine acid removes the lime from it. Thus, it happens that when fluorite is calcined, marine acid absorbs lime and iron to the exclusion of spathic acid and that by this combination it produces the beautiful phenomenon that must accompany it. The result is the oxygenation and bleaching of the ferruginous lime, and finally the sparkling that is probably due in large part to [173] emission of a small amount of oxalic acid gas precipitated by marine acid.

According to the nature of the substance producing it, phosphorescence by impact may or may not be subordinated to that produced by contact with a hot body. Thus, phosphatic chalk of which I have spoken is very phosphorescent by impact and not at all

17. Remarques sur le spath-fluor, traduit du Suédois de M. Scheele par Madame P*** de Dijon. *Observations sur la Physique*, 1783, 22, 264-269. Madame P*** is Claudine Picardet, close friend of L.B. Guyton de Morveau, and wife of another academician of Dijon.

18. Unknown author on spathic acid, reference too imprecise to be traced, *Nova Acta Regiae Societatis Scientiarum upsaliensis*, vol. II.

by heat. Fluorite having a granular surface, is phosphorescent by impact and to a great extent it loses this property by calcination.

It is possible that the two phosphorescences have in part the same cause, when, as in fluorite, phosphorescence by heat is certainly a result of decomposition caused by the dry treatment, for it is likely that in this case, friction produces the same effect as contact with a hot body.

HISTORY OF THE DOLOMITE CONTROVERSY

A chronological analysis of the term dolomite shows that mineralogists were led astray for many years by the definition given by N.-T. de Saussure on the basis of his analysis of 1792. Today known both as a mineral and as a rock, dolomite was given different names depending on its occurrence as a well-crystallized mineral or a rock.

It can be argued that Linnaeus, as early as 1768 (*Systema Naturae...*, 12th edition) recognized dolomite as a rock under the name of *marmor tardum*, a white translucent marble which effervesces relatively late, occurring near Roedberg, in Norway. But no supporting chemical analysis was given.

Arduino (*Osservazioni chimiche...*, 1779, 1- 4, 32-36), subsequently translated into French by Pasini (1833) and into German by von Morlot (1847), discussed his ideas on the volcanic origin of granites and primary mountains (See Carozzi and Newman, 1990), and attributed a metamorphic origin to a "vein of brilliant white brecciated marble" he observed at Lavina near Ena. This rock, from his chemical analysis (it apparently contained *magnesia alba*) would be designated today as a dolomite. Arduino described this white marble as exposed near the top of Mount Lovegno (today called Novegno) by a large landslide (*lavina* in old Venetian language) which came down on the west slope of the mountain above the village of Ena (today Enna). This thick and extensive vein of white marble, which can be seen from far away because of its unusual color, disappears inside the mountain between common limestones. [The location described by Arduino is in the Vicentino, between Schio and Arsiero, where Jurassic-Triassic folded and faulted limestones with intercalated crystalline dolomites are intruded by Triassic rhyodacites and rhyolites and by Paleogene-Miocene alkaline and subalkaline basalts (See *Carta Geologica d'Italia*, 1:100,000, Sheet 36, Schio).

The pertinent text of Arduino can be summarized as follows:

A. J. Retzius and T.O. Bergman demonstrated that magnesia was a characteristic earth although very similar to the calcareous one. Therefore, I shall not deny that magnesia as found on our globe is a specific mineral species, but I disagree on two points. First, that it is an original species — an earth which was always in its present state — and second, that a force does not exist in nature capable of transforming a substance and give it another form.

I believe with A. Beaumé that *magnesia is nothing else but a calcareous earth changed to that state by a natural transformation*. My belief is based on the phenomena

I have observed in places where marbles occur together with other rocks which were involved in these transformations. I have always found magnesia within materials of volcanic aspect [such as true granites of primary mountains] or strangely mixed with them. The marbles (or transformed rocks) of Lavina, near Ena, and similar ones occur, as far as I could observe, only in large fissures of the calcareous rocks of our mountains. The fractures show that these marbles extend vertically or close to that direction to great depths, and appear to have been formed in the past by a subterranean igneous force. The materials filling in this way fissures in our Alps, at times very extensive and very wide, have features indicating that they underwent the action of fire (*bruciamento*) or melting. These marble carry also the traces of fracturation, and several varieties show in a confused manner to consist of fragments of different sizes separated by interstitial veins, so that a brecciated aspect is developed.

When thinking about the origin of these marbles, I can only imagine that they originated from the same limestones whose fissures enclose them. These limestones were broken and crushed by the volcanic fire, calcinated, and by an unusual process enriched in magnesia so that their color changed from dark gray to a very brilliant white. They were also mixed in a strange way with other burned (*bruciate*) materials, and finally lapidified again (*rimpietrite*) by the action of circulating waters. In summary, these rocks took on their new form by changing from the state of ordinary limestones to that of marbles.

I visualize that the portion of these marbles, which together with sulfuric acid formed magnesian spar, was nothing else but calcareous earth which through fiery subterranean action acquired its new specific properties.

Supporting even more my interpretation is the fact that the limestone beds of the mountains which enclose the veins of marbles and the massive marbles surrounding them do not contain any traces of magnesia.

In crystal form, dolomite had been known in a variety of countries, particularly as saddle-shaped pearly-looking crystals ever since 1779 (Woulfe, *Phil. Trans. Royal Soc. London*, 69, compound spar). It was described by many authors: in English as rhomboidal spar, magnesian spar, pearl spar in part; in French as *chaux carbonatée magnésifère*, *chaux carbonatée magnésienne*, *chaux carbonatée magnésiée*, *spath magnésien*, *spath perlé* in part; in German as *Bitterspath*, *Rhomboidspath*, *Rhomboidalspath*, *Rautenspath*, *Kohlensäuerter Kalkerde*, *Bitterkalk*, *Bittersalzerde*.

An updating summary with analyses of *Bitterspath* or *Rhomboidalspath* was given by Klaproth (*Beiträge...*, vol. 1, 1795). He wrote that it occurs as isolated, white to gray, yellowish and reddish, transparent, rhombic-shaped crystals in a chloritic schist with silver-colored flakes of talc, called *Schneidestein* in the mountains of Tyrol and Salzburg. Its composition from a sample from Tyrol is:

<i>kohlensäuerter Kalkerde</i> (calcium carbonate)	52
<i>kohlensäuerter Bittersalzerde</i> (magnesium carbonate) . . .	45
braunsteinhaltigem Eisenkalk (iron oxides)	3
Total	100.0

Another sample from Taberg in Wermeland, a province of Sweden, has less magnesium carbonate with the following formula: calcium carbonate 73, magnesium carbonate 25, and iron oxides 2.25, total: 100.25.

In 1791, Dolomieu published his discovery of a widespread rock in the Tyrolian Alps which was weakly effervescent with acid (*Journal de Physique*, 39). In 1792, Delam  therie mentioned *spath magn  sien* or *Bitterspath* of the Germans in his improved translation (*Manuel du min  ralogiste...* vol. 1, p. 207) of T.O. Bergman's *Sciagraphia regni mineralis*, 1782). He wrote: "It is a combination of the magnesian earth with fixed air. The sample I examined is in a steatite of Corsica which contains octahedral iron (magnetite). It shows semi-transparent spathic blades with the greasy luster of all the stones of this kind. Its color is dull white. Its hardness not very high and its crystal form could not be determined."

In 1792, Nicolas-Th  odore de Saussure published his paper entitled "Analyse de la dolomie" (*Journal de Physique...*, 40) in which he proposed the name *dolomie* on the basis of a suite of samples from Tyrol provided by Fleuriau de Bellevue and by Dolomieu himself. Saussure stated that he had not observed any crystalline form, but that his samples had a salt-like crystalline texture, indicating that the mineral was susceptible to occur in crystal form. Average specific gravity was 2.850. His analysis indicated that dolomite was a combination of calcareous earth 44.29; clay (alumina) 5.86; iron 0.74; and CO₂ 46.1; a little magnesium earth 1.4; loss 1.61; total: 100.00. He expressed his surprise (p. 168) at the relatively high content of alumina, investigated if the clay contained in the analyzed sample was not accidental, but found that all his samples contained clay at least in that amount, although they were all as white as the Carrara statuary marble (p. 162). He felt that the slow solubility in acids was due to the fact that the combination calcium carbonate-clay was difficult to attack.

In essence, the new rock designated by N.-T. Saussure as dolomite, was interpreted by him as very rich in carbonic acid, almost devoid of water, containing calcareous earth and clay, but apparently little magnesia, that is, in modern terms, a double carbonate of calcium and aluminum, hence a combination difficult to be attacked by acids. It entered mineralogy under the name of *chaux carbonat  e aluminif  re* and a long-lasting controversy began.

In 1794, Kirwan (*Elements of Mineralogy*, 2nd edition) included a section on "Calcareous Genus" in which he mentioned all those earths and stones, apparently homogeneous, in which calcareous earths predominate. This genus had a 4th species "mixed with magnesia" called *Muricalcite*, containing a 3rd family, crystallized, called *Compound spar*, *Bitter spar* of the Germans (vol. 1, p. 92-93). He wrote as follows: "it consists of grayish white rhomboidal crystals, transparent and pearly, hardness: 8, specific gravity: 2.480. It does not effervesce with acids until it is pulverized, and then gently, though completely soluble in them; if previously heated it will dissolve more quickly. According to Klaproth's analysis (1794) it contains 52% mild calx (calcium carbonate), 45% mild magnesia (magnesium carbonate), and 3% of iron mixed with manganese. It is found in Tyrol and generally mixed with chlorite and talc."

The 9th species of the Calcareous Genus of Kirwan is designated as supersaturated with fixed air, frequently phosphorescent, and called *Dolomite* (vol. 1, p. 111-112) with a first family *Common dolomite*, *Dolomite of Saussure* (1792). This species is described by Kirwan as follows: "pure or grayish white or light red, yellowish white, transparent with luster, hardness: 8-9, specific gravity: 2.85 to 2.862, effervesces slowly with acids unless pulverized, phosphorescent upon impact. According to the analysis of M. Saussure, the younger: 100 parts of it contain 44.29 calx (calcium carbonate); 5.86 argill (*sic*, alumina); 1.4 magnesia (magnesium carbonate); (0.074 *sic*), 0.74 iron; and 46.1 fixed air. Hence, we see that the lime in this stone is united to a much greater proportion of fixed air than in other limestones. Does this not proceed from its containing an excess of the carbonic principle?

Mr. Dolomieu has the merit of having first drawn the attention of mineralogists to this sort of limestone. Hence, M. Saussure, junior has distinguished it by the name of this justly-celebrated geologist. His analysis is replete with many new and important observations."

In 1796, H.-B. de Saussure (*Voyages dans les Alpes...* (vol. IV, § 1812) wrote in his description of the Mountain of Pesciumo, in the St. Gothard under the heading *Dolomie grenue*: "I encountered also beds of a stone which at first sight could be taken for a fine-grained sandstone. This gray-reddish stone, with weakly coherent grains, is a dolomite (See analysis of the dolomite by my son, *Journal de Physique*, 40, 167) mixed with a small amount of mica and quartz. It is recognizable by its weakly and long-lasting dissolution in acids, as well as by *the clay intimately combined with the calcareous earth which is typical of its composition* [our underlining]. Its beds are thin and almost vertical." Further on (*Voyages dans les Alpes...*, vol. IV, § 1929), Saussure wrote under the heading *Calcaire dolomie*: "It is remarkable to observe that the saline or granular limestones of the St. Gothard are almost all slowly effervescent and of the species my son analyzed [*Journal de Physique*, 40, 167] to which he gave the name *Dolomie* in honor of M. le Commandeur de Dolomieu who was the first to attract the attention of naturalists to this unusual stone. This rock in the St. Gothard area (Pesciumo, Campo-Longo, Fiéüt, and other places) is either pure, clear-white, fine grained, weakly coherent and translucide, or mixed with small crystals of tremolite for which it forms the groundmass, or including itself layers of beautiful green mica. It seems most often to be schistose, particularly when mixed with mica. A variety of the schistose type, which is flexible, was discovered by M. Fleuriau de Bellevue at Campo-Longo, in the Levantine Valley" (See Fleuriau de Bellevue, *Observations sur la Physique*, 1792, 41, 86-91, and A.V. Carozzi, *S.P.H.N., Mémoires* 1990, 45, 2, p. 19 and 23).

In 1797, J.-C. Delamétherie (*Théorie de la Terre...*, 2nd edition, vol. 2, p. 65-66) included in his treatise of mineralogy a section entitled *Des Pierres argilo-calcaires*. He stated that they are extremely common, and represented by a variety of rocks such as marbles, limestones, and calcareous shales. He wrote: "*Dolomie* is also a calcareous stone mixed with an appreciable proportion of argillaceous earth. Saussure fils extracted

from it: *chaux* 44.29; *alumine* 5.86; *magnésie* 1.4; *oxyde de fer* 0.74; *acide carbonique* 46.01. It is very phosphorescent."

In 1799, Smithson Tennant (*Philosophical Transactions Royal Society of London for 1799*, 69, 305-314; *Scherers Journal der allgemeine Chemie*, 1799, 5, 423-429, and also *Journal de Physique*, 1800, 51, 156-163) discussed the use of lime in agriculture. He observed that in the region of Doncaster (South Yorkshire) two kinds of lime were used which were supposed to have strikingly different effects. One made land fertile whereas the other diminished the fertility of the land; when a heap of the latter was left on a spot, all vegetable growth was inhibited for many years. His chemical analysis of the latter lime indicated that it contained 3 parts of calcareous earth and 2 parts of magnesia, and hence was a pulverized magnesian limestone. Tennant wrote: "Magnesian limestone may be easily distinguished from that which is purely calcareous, by the slowness of its solution in acids which is so considerable that the softest kind of the former is much longer in dissolving than marble. From this property of the magnesian limestone, there appeared to be reason to suspect that the kind of marble which had been called Dolomite, from M. DOLOMIEU, who first remarked on its peculiarity in dissolving slowly, might also be similar in its composition. An analysis of this substance was lately given in the *Journal de Physique*, but this is probably erroneous [our underlining]; for upon examining three specimens, they were found to consist of magnesia and calcareous earth, like the magnesian limestone; so that it ought, no doubt, to be considered as the same species of stone, but in a state of greater purity.

The pieces of Dolomite were from different places; one of them being found among the ruins of Rome, where it is thought to have come from Greece, as many statues of Grecian workmanship are made of it, and no quarries of a similar kind are known in Italy; the second was said to have been thrown up by Mount Vesuvius (see A.V. Carozzi, *S.P.H.N., Mémoires* 1990, 45, 2, p. 110 for a discussion of the xenoliths of Vesuvius), and the third was from Iona, one of the western islands of Scotland.... The crystallized structure of magnesian limestone seems to show that it has not been formed by the accidental union of the two earths but must have resulted from their chemical combination."

The German version in Scherers *Journal der Chemie*... is identical to that published in *Phil. Trans. Royal Soc. London*, but with respect to Saussure's analysis it says: "The analysis of this substance, published in the *Journal de Physique*, seems to have been probably erroneous. Indeed, after testing three samples, I found that it consisted of magnesia and calcareous earth, like the magnesian limestone [*talkartige Kalkstein*]. Therefore, it should be considered the same type of rock, but in a much purer form." In a footnote, the reference is given to *Journal de Physique*, 40, March 1792, 161-169 [pagination excluding the discussion on phosphorescence of other calcareous rocks] as follows: "The analysis is by Saussure the Young. According to it, the dolomite consists of: 44.29 *Kalk*; 5.86 *Thon*; 1.4 *Talk*; 0.74 *Eisen*; und 46.1 *Kohlensäure*."

It is interesting to notice that only the German version of Tennant's article explicitly attributed the analysis of dolomite to N.-T. de Saussure whereas the English

and French texts, perhaps still influenced by 18th-century courtly manners, mentioned only the *Journal de Physique*, omitting the author's name. Or did perhaps the English and the French respect the name of H.-B. de Saussure so highly that they did not want to accuse his son of any wrongdoing?

Tennant's paper appeared again in French translation-without the author's name-in the *Journal de Physique* (1800, 51) saying: "An analysis of this substance was recently published in the *Journal de Physique*, but it was probably erroneous."

After publication of the various versions of Tennants' article, N.-T. de Saussure apparently realized his mistake and undertook an extensive series of experiments on the possible combination of alumina with carbonic acid, accompanied by a complete review of the work of all previous authors who dealt with carbonates of alumina. His long work was published in 1800 under the title "Recherches sur l'alumine" (*Journal de Physique...*, 52). He reached the following conclusions (p. 289-290):

1. Alumina does not form with carbonic acid a solid carbonate of alumina, or at least such a combination has not as yet been obtained artificially.
2. The substance, considered today a solid carbonate of alumina, results from the combination of alumina with alkali and carbonic acid. This acid enters into this combination only because of its affinity with the alkali.
3. Alumina seems to be able to combine with carbonic acid only when the latter is dissolved in water. When this earth precipitates from the solution by vaporization of the carbonic acid, it is not in the state of a carbonate.
4. Several types of natural clays, considered by some authors carbonates of alumina, do not appear as such.

In summary, N.-T. de Saussure reached the conclusion that a solid carbonate of alumina could not be formed experimentally and that it did not exist as a mineral in nature. Furthermore, he added that analytical procedures currently used to determine the amount of alumina could lead to rather large errors.

Returning to the question of his analysis of the dolomite (p. 284) he wrote: "I take now as doubtful that calcareous earth alone could be an adequate intermediate in the combination of alumina with carbonic acid. When I thought to attribute to this cause the great quantity of carbonic acid I discovered in dolomites, I did so because I was led astray by alumina which was *extraordinarily* [our underlining] abundant in the samples I analyzed. Mr. Tennant was more correct by attributing the properties of dolomite to a triple combination of carbonic acid with calcareous earth and magnesia which dolomites always contain in appreciable amount, whereas the purest dolomites contain only an extremely small quantity of alumina. Essentially, dolomite is to the *bitter-spath* of the Germans what marble is to calcareous spar [calcite]."

The faulty laboratory procedures used in 1792 by N.-T. de Saussure in his original analysis of dolomite led obviously to a deceptively high content of alumina and to a simultaneous elimination of most of the magnesia. In the absence of any extant samples, it is difficult to understand the discrepancy between his earlier statement, that the analyzed dolomies were as white as Carrara marbles, and the later one that they were

extraordinarily rich in clay. This honorable *mea culpa* of N.-T. de Saussure, included in a publication dealing with investigations on alumina, a non-informative title, apparently did not attract the required attention. As Tennant's articles, with a similar type of title, it was totally ignored by the authors of textbooks and the error continued to appear in print.

In 1801, Haüy in *Traité de Minéralogie...* (vol. 2, p. 173-175) described under the general heading of *Chaux carbonatée*, I. *Chaux carbonatée aluminifère* with synonyms given as *Dolomie* (H.-B. de Saussure, *Voyages dans les Alpes...*, 1796, § 1929), and *Common dolomite* (Kirwan, *Elements of Mineralogy*, 1794, vol. 1, p. 111). Haüy stressed the white or gray color, granular texture, massive to schistose aspect, phosphorescence by impact, and quoted the analysis by Saussure fils: *chaux* 44.29; *alumine* 5.86; *magnésie* 1.4; *oxydes de fer* 0.74; *acide carbonique* 46.00; *perte* 1.71; *total*: 100.00. He mentioned that the name dolomite was given in honor of the discoverer, the famous Dolomieu. It occurs in layers in Mount St. Gothard and in many other places. The white and gray varieties sometimes contain mica in small rhomboidal blades. Dolomite may be associated with metallic substances such as: realgar, chalcopyrite, and chalcosite. Transitions exist between dolomite and saccharoidal carbonate marble.

In the same book (vol. 2, p. 187-188), Haüy described under the heading of IV. *Chaux carbonatée magnésifère* with synonyms given as *spath magnésien* (Delamétherie, *Manuel...*, 1792, p. 207); *limestone mixed with magnesia* (Kirwan, *Elements...*, 1794, p. 92); *spath magnésien* (Brochant de Villiers, *Traité...*, 1801, vol. 1, p. 560). He gave the analysis of a specimen of *Bitterspath* from Tyrol by Klaproth (*Beiträge...*, 1795, vol. 1, p. 304), and mentioned occurrences in the mountains of Tyrol and Salzburg, in Wermeland, a province of Sweden. He stated that the samples he examined were incrustated in a schistose talc.

It is clear that the dichotomy and confusion continued in spite of Tennant's papers of 1799, their French translation of 1800, and Saussure's paper of the same year.

In 1802, Reuss in his *Lehrbuch der Mineralogie...* included a section (Part 2, Vol. II, 273-284) on *Körniger Kalkstein* or granular limestone in which he stated (p. 280) that it included two varieties: 1. *Biegsame körniger Kalkstein* or elastic marble described by Fleuriau de Bellevue (See A.V. Carozzi, *S.P.H.N., Mémoires*, 1990, 45, 2, p. 19 and 23), and 2. *Der Dolomit* which is fully described (p. 282-284).

The description is preceded by a list of previous quotations: Dolomieu, *J.P.*, 1791, Fleuriau de Bellevue, *J.P.*, 1792, N.-T. de Saussure, *J.P.* 1792, H.-B. de Saussure, *Von Crells Annalen der Chemie*, 1795, H.-B. de Saussure, *Voyages...*, vol. 4, 1796, Delamétherie, *Théorie de la Terre*, vol. II, 1797.

Reuss' description is as follows: "Dolomite, also a granular limestone, is snow-white, grayish or milky white with transitions to blue-gray varieties. Its fracture is irregular, at a large scale it is poorly developed and wavy schistose, at a small scale it grades from uneven through splintery into clearly granular, thus providing the transition to massive limestones. The edges of samples are more or less translucent, in places entirely opaque. Dolomite is hard, gives off sparks when struck by steel, but is not particularly heavy. Its specific gravity, according to Saussure, is 2.850. Upon impact, it

is phosphorescent in darkness. A fragment of dolomite, when placed in Saussure's apparatus, becomes at first white, then its margins become translucent, and finally at 3024° dolomite becomes a transparent and slightly vesicular glass which effervesces upon contact with sappare [kyanite]. When a small fragment of dolomite is attached to a piece of massive limestone, it melts also into a small spherule. With acids, its effervescence is barely visible.

According to the analysis by Saussure the Young, its composition is *Kalk* 44.29; *Thon* 5.86; *Talk* 1.4; *Kohlensäure* 46.1; *Eisenoxyd* 0.75.

Occurrences: Lombardy, Switzerland (Gothard at Presciumo, Campo-Longo, Fiéüt), Salzburg, Tyrol, Bohemia (near Kallich in Saatzer Kreise). It is schistose, and mixed with apple-green to silverish flakes of talc and contains abundant mica and quartz. The variety from Gothard contains also some small crystals of common tremolite. The hardness of dolomite originates from its intimate mixture with quartz. Its designation is from Dolomieu who was the first to draw attention to this fossil [mineral]."

In 1801-1803, Brochant de Villiers in *Traité élémentaire de minéralogie*, (first edition and second edition of 1808, both with same pagination, vol. 1, p. 533-535) under the headings of *Genre calcaire, pierre calcaire grenue*, described varieties called *dolomies* which release a phosphorescent light when strongly scratched in darkness. His description of dolomite is similar to that of Haiüy, but he said that it seemed that Linnaeus had previously mentioned marbles that did not effervesce with acids or at least very slowly. He mentioned that Nicolas-Théodore de Saussure designated this variety of calcareous rock as *Dolomie* after the name of its discoverer, as a small recognition of the talents of one of the greatest geologists, and that the name had been approved by all naturalists. He also quoted Saussure's analysis.

In the same book (Vol. 1, p. 560-562), Brochant de Villiers described *Bitterspath* or *spath magnésien* from Tyrol and Sweden in the same way as Haiüy and quoted Klaproth's analysis (*Beiträge...*, 1795, vol. 1, p. 304). He said it was always accompanied by other magnesian substances, such as asbestos, tremolite, and talc, and was scattered in chloritoschists, serpentines, and talcschists.

Thus, the dichotomy and confusion were further carried on.

In 1802, Klaproth (*Beiträge...*, vol. 3, p. 292-296) published a chemical analysis of the greenish mineral *Miemit* whose name was derived from Miemo, in Tuscany where it was found in cavities of alabaster. The mineral was sent to him by D. Thomson in 1791 under the label "magnesian spar." Klaproth confirmed that *Miemit* had the same composition as the *Bitterspath* from Tyrol he had analyzed in 1795 and that it should be considered only as a variety of the latter (composition of *Miemit*: calcium carbonate 53; magnesium carbonate 4.25; iron oxides 3; total: 98.50).

D. Thomson was in fact G. William Thomson (1761-1806), an eccentric and still very little-known naturalist whose double life baffled historians for many years. He studied medicine, but after becoming professor of anatomy at Oxford, he abruptly resigned and settled at Naples for the rest of his life. Known as Dr. Guglielmo

Thomson, he played an important role in Italy by his studies of mineralogy, paleontology, volcanoes, and meteorites. He had many contacts in Geneva, particularly with Marc-Auguste Pictet. See A.V. Carozzi, *S.P.H.N., Mémoires*, 1990, 45, 2, p. 68, 95, 110, 170, 191 for an account of his varied contributions. See also, R.T. Gunther, *Nature*, 1939, No. 3625, 667-668, and C.D. Waterston, *Univ. Edinburgh Journal*, Autumn 1965, 122-134.

Klaproth also analyzed a prismatic *Bitterspath* from cobalt ore veins of Glücksbrunn, near Gotha (*Beiträge...*, 1802, vol. 3, 297-303) which consisted of calcium carbonate 33; magnesium carbonate 14.50; iron oxide 2.50; CO₂ 47.25; water and loss 2.75; total: 100.00.

Finally, in 1807, Klaproth, in "Chemische Untersuchung des Dolomits" (*Beiträge...*, vol. 4, p. 204-223) described a dolomite from Campo-Longo in the St. Gothard (see H.-B. de Saussure, *Voyages...*, 1796, vol. IV, § 1929) which contained small blades of mica and thin streaks of greenish talc. He gave the analysis of dolomite by N.-T. de Saussure (with slight mistakes: CO₂ 46.00 instead of 46.10, and loss 1.71 instead of 1.61) and wrote that on the basis of this analysis, Haüy (*Traité...*, 1801, vol. 2, p. 173) in his discussion of dolomite called it *chaux carbonatée aluminifère*. He continued: "Smithson Tennant had previously raised doubts about the accuracy of this analysis. I have confirmed this doubt on the basis of my own experience and by means of the analyses given below. These analyses show that this fossil [mineral] has a much greater content in magnesium, but does not have the slightest trace of alumina. Therefore, dolomite should find, in the future, its place in the mineral system within the division of the magnesium-bearing calcareous minerals, to which bitterspar, siderite, and miemite belong."

Klaproth then gave the analysis of the dolomite of Campo-Longo after elimination of the micaceous particles: calcium carbonate 52; magnesium carbonate 46.50; iron oxide 0.50; manganese oxide 0.25; loss 0.75; total: 100.00. The remainder of the paper concerns the analyses of other dolomites from the Apennines, the Alps of Carinthia, and an antique dolomite from the island of Tenedos, more beautiful than the Paros marble. The results were similar, but with slight variations in the content of magnesium carbonate, variations which he attributed to their different locations and geological ages. On the basis of these variations, Klaproth raised the question whether the term dolomite by itself was sufficient or whether it should be preceded by a designation of age and location.

In 1807, Brongniart in his *Traité élémentaire de minéralogie* (vol. 1, p. 229-232) under the heading of *Chaux carbonatée lente Dolomie* (synonym: *chaux carbonatée aluminifère*, Haüy, *Traité...*, 1801, vol. 2, p. 173-175), recapitulated the characters of dolomite and listed new occurrences in Siberia, England, and France. He wrote in a footnote (p. 231): "This rock was considered a combination of calcareous earth and alumina. M. Smithson Tennant was the first to show (*Journal de Physique*, 1800, 51, p. 156) that the earth combined with calcareous earth in dolomite was magnesia. M. Klaproth has just confirmed this observation (*Beiträge...*, 1807, vol. 4, p. 204-223)."

Whereas Brongniart was simply up to date in the designation of dolomite, Karsten went beyond that stage. He must have been in contact with Haüy (who was preparing his 1809 book) because he wrote in *Mineralogische Tabellen...* 1808 (p. 50-51) under the heading of *Kalkerde mit Kohlensäure*:

1. *Gemeiner Dolomit* (synonym: *chaux carbonatée magnésifère granulaire*, Haüy) with the following analysis: calcium carbonate 52.00; magnesium carbonate 46.50; iron oxide 0.50; manganese oxide 0.25; loss 0.75; total: 100.00 (Klaproth, *Beiträge...*, 1807, vol. 4, p. 209).

2. *Rhomboëdrischer Dolomit* (synonym: *Rautenspath*, *Bitterspath*, *chaux carbonatée magnésifère*, Haüy) with the following composition: calcium carbonate 52.00; magnesium carbonate 45.00; iron and manganese oxides 3.00; total: 100.00 (Klaproth, *Beiträge...*, 1795, vol. 1, p. 304).

Karsten stated in footnote 64 (p. 93) that on the basis of the complete identity between *Bitterspath* and *Dolomit*, both from an oryctognostic and geognostic viewpoint, he did not hesitate to call them both *Dolomit* and to replace the now obsolete terms of *Bitterspath* and *Rautenspath* by *rhomboëdrischer Dolomit*.

This was the first time that dolomite, in individual crystals, and dolomite, as a rock, were finally designated as the same mineral. The controversy initiated by Saussure's paper was thus brought to an end after 16 years.

Haüy in his *Tableau comparatif...* of 1809 (Appendix, p. 5-6) made the change even more precise. Under the heading of *Chaux carbonatée magnésifère*, he mentioned two forms:

1. *Chaux carbonatée magnésifère à forme cristalline déterminée* (synonym: *Rhomboëdrischer Dolomit*, Karsten, 1808, p. 50-51).

2. *Chaux carbonatée magnésifère granulaire* (synonym: *Gemeiner Dolomit* Karsten, 1808, p. 50-51), *vulgairement Dolomie*, *chaux carbonatée aluminifère* (Haüy, *Traité...*, 1801, vol. 2, p. 173-175).

Subsequent treatises on mineralogy by Hoffmann (1811-1818, vol. 3, part I, 57-59), Hausmann (1813, 963-966), and many others repeated the final interpretation from that time on.

However, some authors still remained unaware of the problem. For instance, von Morlot (1847) who, as mentioned above, had stressed the interest of the apparently forgotten metamorphic interpretation of a brecciated marble (dolomite) by Arduino in 1779. Von Morlot, in his discussion of dolomite, mentioned the original letter of Dolomieu of 1791 as well as the "elaborate mineralogical analysis, definition by chemical analysis of the rock and naming of the rock dolomite" by N.-T. de Saussure in 1792, apparently without realizing the erroneous character of the analysis.

More details on the circumstances which led to the erroneous analysis by N.-T. de Saussure appear warranted. He wrote in his paper (*Journal de Physique...* 1792) that the analyses were based on samples provided to him by Fleuriau de Bellevue upon his return from a joint trip to the Tyrolian Alps, and that Dolomieu himself sent him beautiful samples of the major types of dolomites later on. In his paper (*Journal de*

Physique..., 1791), Dolomieu wrote that his trip had been taken "18 months ago," the paper dated January 1791 puts the trip during the summer 1789. Fleuriau de Bellevue being a frequent visitor of Geneva, it can be assumed that N.-T. de Saussure, who at the time was only 23 years old, undertook the analysis of the first batch of samples some time between fall 1789 and fall 1791. He was then already deeply involved in his major studies, chemical experiments on plant physiology, in which he was to achieve fame as the founder of agricultural chemistry with his book *Recherches chimiques sur la végétation*, published in 1804.

After completing the analysis of the samples brought by Fleuriau de Bellevue, he sent a letter to Dolomieu (found neither in the Archives Saussure nor in the Archives Dolomieu in France) with his major results. However, the content of the letter can be reconstructed from Dolomieu's reply. The Saussure's archives contain the manuscript of a lengthy reply by Dolomieu, dated Paris, October 31, 1791 (*BPU, Archives Saussure, No 201, letter 14*, also published by Lacroix, 1921, vol. 2, 24-29), which is of great interest in many respects. It reads, in part: "I would like to thank you, dear Sir, for having taken care of the kind of calcareous stones upon which I drew the attention of naturalists. The analysis you have just completed bestows upon it an interest I could not have given it myself because I gave a mere description of its conditions of occurrence.

I was even grossly mistaken in regard to the amount of [fixed] air I assumed it contained because I believed it had a much smaller amount of this fluid than ordinary calcareous rocks, whereas you found it much more abundant. My mistake originated from the fact that this stone seemed to lose less weight by calcination than pure calcareous rocks; observing also a slow and always less intense effervescence, I thought that it lacked fixed air. You have also discovered that it is almost entirely devoid of water, which is an essential constituent of the other rocks of this type, and this peculiarity is much more interesting than those I noticed in it. Your discovery is extremely important and I consider myself very fortunate to be able to provide you with the means to repeat your experiments which should further its demonstration. Therefore, I am sending you samples on which you can repeat your tests. Being away from my cabinet, I cannot offer you all the varieties which are as numerous in this kind of rock as in those which give an instantaneous and strong effervescence. But, the four samples you will receive are the major types and should suffice for your analyses. I think, dear Sir, that you will find that they have a specific gravity higher than that which you determined on the small samples given to you by Fleuriau de Bellevue. The specific weight of sample No. 2 is close to 3.000, for the other three it is around 2.900, unless my instruments and my calculations led me astray, a fact I cannot verify now.

Sample No. 1 was very phosphorescent; it seems to me that it lost some of this property since it was enclosed in plaster in order to be sawed.

Sample No. 2 always emitted less light. These two marbles come from the mountain called Brenner in Tirol; their beds are almost vertical and associated with rocks of various other types.

Sample No. 3 is a calcareous stone in horizontal beds which surrounds and, in places, overlies the mountains of porphyry between Bolzano and Trento. It gives off sparks with the tinder box, but is not phosphorescent. Kindly observe inside its paste imprints of shells, mostly screws [gastropods].

Sample No. 4 is a slab of the beautiful statuary marble, called *Marmo greco duro* which should rank first among the stones used in fine arts, but the location of its quarries is unknown. I am sorry to have only a small fragment to give you, perhaps it would be a pity to destroy it for purposes of analysis.

Since I published my memoir (*Journal de Physique...*, 1791), many naturalists searched and found phosphorescence in many other calcareous stones which, otherwise, do not differ from common ones by any other characters, namely they give the same effervescence with acids. In my experiments, I did not find this property [phosphorescence] in a greater number of samples, because I worked sometimes in daytime although in dark rooms, but my eyes still influenced by sunlight could not be sensitive to the phosphorescent glow of the rocks. Therefore, these types of tests should always be performed at night.

I would request, dear Sir, that you mention in your forthcoming memoir the names of Mr. de Laumont, who last August read some observations on this subject at the Society of Natural History of Paris, and the abbot Fortis, who just sent me a letter describing eight varieties of marbles of different colors: white, whitish, yellowish, grayish, greenish, and olive-green, all of them from the volcanico-marine mountains called Euganean, near Padova. They are all fine-grained, with conchoidal fracture, very hard and very heavy, but they are effervescent. Therefore, phosphorescence is an accidental property which characterizes many species of calcareous rocks.

Your question concerning the name to be given to the kind of calcareous stone with weak effervescence, embarrasses me. First, I would like to say that the naming is yours because you have demonstrated, by chemical analysis, its most important characteristic, which depends directly upon its composition, namely the absence of water, and without which it would not deserve a specific name. If this rock belonged only to the mountains of Tirol, you could have called it [*marmor*] *tirolensis*, but it occurs in many other mountains, such as the Alps of Switzerland, Savoy, and Italy. As far as I am concerned, dear Sir, I have, for a long time, thought of using the right which the botanists attributed to themselves when discovering a new plant, namely to express friendship, gratitude, or respect by giving it the name of a person. If I were lucky enough to make an important discovery in lithology, I would have given to the new substance the name of your father as an expression of my admiration and my gratitude for the enlightenment he brought to a science which affords me the greatest enjoyments. However, I would like to be sure that my tribute would be worthy of him."

The remaining three pages of Dolomieu's reply pertain to samples of various types of lavas which were part of his classification of volcanic rocks that he wished to show H.-B. de Saussure.

The letter terminates saying, "For a long time now, I have wished to make the personal acquaintance of your father. I would have thousands of questions to ask him, and thousands of explanation to receive. Unfortunately, political circumstances in France compelled me to postpone to some other time the project of visiting your beautiful mountains, were it at least by following the books of your father [*Voyages dans les Alpes...*] if I did not get the chance to accompany him in some of his field trips. I beg you, dear Sir, to express to him my respects and best wishes.

I congratulate you, dear Sir, to begin an illustrious career in which your young age and the footprints of your father forecast the greatest success. I shall always be the first to applaud your works, and be interested in reading all your forthcoming publications. As far as I am concerned, political problems occupy all the minds to such an extent that sciences have almost become foreign matters.

Kindly accept, dear Sir, my thanks for the opportunity of becoming acquainted with you, and the expression of my sincere friendship.

Yours faithfully,

Le commandeur Déodat de Dolomieu

P.S. You will receive the above-mentioned box by the Paris-to-Geneva stagecoach which leaves today Monday and should arrive in Geneva by the end of the week. It is prepaid."

Dolomieu's letter deserves some comments. The samples of dolomite sent to N.-T. de Saussure are those described in Dolomieu's paper of 1791 (*Journal de Physique...*), their geological setting was previously discussed (see translation of Dolomieu's paper by Carozzi and Zenger, 1981). Dolomieu was apparently very impressed by N.-T. de Saussure's analysis, particularly by the quasi absence of water and the high amount of fixed air (CO_2), distinguishing dolomite from other calcareous rocks. He obviously accepted the idea immediately that dolomite was a combination of calcareous earth with clay and fixed air, and that the slow effervescence resulted from the difficulty of acids to attack such a combination, and finally that phosphorescence was not a typical feature of this new rock type.

It is of great interest to read that if Dolomieu himself had undertaken the chemical analysis of the weakly effervescent calcareous rock, then he would have called it saussurite, in honor of H.-B. de Saussure. The history of saussurite is as follows. H.-B. de Saussure (*Voyages dans les Alpes...*, 1779, vol. 1, § 112; 1796, vol. 3, § 1313) described under the heading of *jade* an unusual mineral of the steatite group, frequently found around Geneva in pebbles and in large blocks [Pleistocene glacial outwash and erratic boulders], in which it forms the groundmass for a variety of types of tourmaline crystals. According to Saussure, this unusual type of jade has a high degree of hardness, greater than that of chert, and the best hammers cannot break it. Its external surface is shiny, greasy to the touch, and its fracture surface recalls that of a congealed oil, its yellowish color and semi-transparency increase also this resemblance. For Saussure, this new variety of jade differs from the well-known green oriental jade by its greater hardness and higher density, but he did not give a particular name to it.

In 1801, R. J. Haüy (*Traité de minéralogie*, vol. 4, p. 368) called it *Jade tenace ou Jade de Saussure*. In 1806, Nicolas-Théodore de Saussure (*Journal de Physique...*, 62, 273-274) in a letter addressed to J.-C. Delamétherie stated that the latter was right (*Théorie de la Terre*, 2nd edition, 1797, vol. 2, p. 352-355) in having classified the oriental jade and the jade found in the vicinity of Geneva as two distinct mineral species. However, he criticized the name *lhemanite* (from Lac Lheman or Léman) given by Delamétherie to the variety of jade from Geneva because he felt that the practice of giving to minerals the names of their places of occurrence was being increasingly rejected. He suggested to give it instead the name of his father who had described this variety of jade very accurately, and to call it saussurite. Two chemical analyses given in the paper of N.T. de Saussure showed the appreciable differences in composition between the oriental jade and saussurite. He published the same year a more complete discussion of these chemical analyses in the *Journal des Mines*, 19, 205-218.

The subsequent history of saussurite is complex and beyond the scope of this paper. According to Dana (*A System of Mineralogy...*, 8th edition, 1888, p. 290, 321, 341), it was considered a variety of zoisite, then of labradorite, until modern techniques of identification of minerals revealed that saussurite was not a mineral, but a complex greenish mineral aggregate resulting from the alteration (saussuritization) of calcic plagioclases into epidotes. It consists actually of a mixture of albite (or oligoclase), zoisite, and epidote, together with variable amounts of calcite, sericite, prehnite, and calcium-aluminum silicates other than those of the epidote group.

Returning now to N.-T. de Saussure's paper of 1792, he did follow Dolomieu's suggestion to mention the names of de Laumont and Alberto Fortis, but he maintained the average specific gravity of dolomite at 2.850. Dolomieu's reply also indicates that the samples brought by Fleuriau de Bellevue were small and that it would be a pity to destroy the sample of *Marmo greco duro* he was sending in the box for analytical purposes. These statements indicate that chances to find the samples analyzed by N.-T. de Saussure are, at the best, remote.

Indeed, the collection of rocks, fossils and minerals of N.-T. de Saussure was bequeathed to the Academic Museum of Geneva, predecessor of the present Museum of Natural History of Geneva, upon his death on April 18, 1845. The manuscript proceedings of the meetings of the Board of Directors of the Academic Museum indicates (685th meeting, July 22, 1845) that the geological portion of the collection was mediocre, but that some fossils were interesting and some minerals outstanding. In a subsequent meeting (690th, September 5, 1845) it was mentioned that the best portion of the mineralogical collection of N.-T. de Saussure, namely 218 samples, had been incorporated into the Museum's collections, and that although some specimens were more beautiful than those previously owned by the Museum, there were no new species or varieties. The rest was apparently discarded. In the catalog of the mineral collection of the Natural History Museum (1841-1845, folios 302-334) describing the samples of the collection of N.-T. de Saussure, only one is labeled "compact dolomite of unknown provenance" (folio 334,

No. 77), but it was unfortunately discarded in May 1899. In summary, it appears that no samples of dolomite analyzed by N.-T. de Saussure have been preserved.

A study of the Saussure's archives at the Public and University Library of Geneva reveals no manuscript draft of the 1792 paper on the analysis of dolomite by N.-T. de Saussure, nor any thorough account of the detailed chemical procedures it contains. However, an interesting, but undated booklet by the hand of N.-T. de Saussure (*BPU, Archives Saussure, No 142*) begins with four pages of carelessly written notes concerning the *Analyse du marmo gr. antiq.* [*Marmo greco antico*] (repeated twice), and the *Analyse de la Dolomie du Tyrol* (Fig. 1). These analyses date the booklet as post-October 1791, date of the above-described Dolomieu's letter. The remaining pages of the booklet, more systematically kept and cleanly written, deal with chemical experiments on plants and seeds. The content of this booklet indicates that the analysis of rocks and minerals was not the major subject of interest of N.-T. de Saussure.

The Saussure's archives (MS 121) contain an undated set of heavily corrected notes entitled: *Recherches sur les combinaisons de l'alumine avec le gaz carbonique, opinion de quelques chimistes sur le carbonate d'alumine*. This manuscript is essentially the first draft of the paper published by N.-T. de Saussure in 1800 under the title "Recherches sur l'alumine" (*Journal de Physique...*, 52). It is peculiar in two ways: it shows numerous changes, involving the handwritings of father and son as if both had closely worked together in repairing the previous damage done to the reputation of Nicolas-Théodore (this could confirm that a naturalist's name was indeed at stake as mentioned above); the manuscript does not contain, for reasons unknown to us, the section dealing specifically with dolomite. The introduction of the manuscript begins as the printed text (§ 1): "One cannot help but being surprised by the fact that most combinations of alumina with acids being today well known, we have only imperfect ideas on the association of this earth with such a widespread substance as carbonic acid." The following text however was not published: "I propose to fill entirely this lack that chemistry shows on this subject. I shall correct the opinions of the other chemists who mentioned carbonates of alumina and I shall present several observations which might be useful to the analytical determination of the precise amount of this earth. This would avoid, in certain cases, the very unreliable results due to the combination of alumina with water."

The review of earlier authors who had dealt with carbonates of alumina (§ 2 of the printed version) ends in the manuscript with the following unpublished section: "Since it is difficult to reach a final conclusion on so many contradictory, and at the same time reliable opinions, which may be equally capable of being different from the truth in certain aspects, I felt it my duty to present the results of the investigations I have completed on this subject, following my own error (*accidentellement*)."

Finally, it appears interesting to mention the little-known fact that another mineral substance was dedicated to Dolomieu, as recalled by Lacroix (1918, p. 87, footnote 100). In 1790, Karl Wilhelm Nose in *Orographische Briefe...*, (p. 198) designated under the name of *déodatite*, a compact, gray-green to blueish substance occurring as blocks within trachytic tuffs of the Brohl valley, in the Lower Rhine area of Germany, which he

interpreted as a variety of prehnite. However, in 1797 in *Beschreibung einer Sammlung...* (p. 10, 27-29), he understood that the substance was in reality a type of pitchstone (pechstein) namely a variety of obsidian with crystallites. Therefore, he decided to restrict the name of *déodatite* to the pitchstone of the Lower Rhine valley and proposed the name of *dolomian* for the pitchstones of the other volcanic regions described by Dolomieu, such as the dolomian-porphyrries of Lipari, Ischia, the Euganeans Hills. In 1809, Nose restated his viewpoint in a paper entitled *Von kryptischen des Dolomians...* but the designation, not accepted by the leading textbooks in mineralogy of the time, disappeared.

The substance described by Nose was also interpreted as a variety of pitchstone by Brongniart (*Traité de minéralogie...*, 1807, vol. 1, p. 35) and by Brochant de Villiers (*Traité élémentaire de minéralogie...*, 1808, 2nd edition, p. 356); in both cases the name was misspelled as *déodalite de Mr. Rose* (sic).

Among the German mineralogists, F.A. Reuss (*Lehrbuch der Mineralogie...*, 1801-1806, part 33, vol. 2, p. 695) interpreted *déodatite* as pleonaste, whereas J.R. Zappe (*Mineralogisches Handlexikon...*, 1817, vol. 1, p. 157) thought also at first it was pleonaste, then opted for *häüyne*.

In summary, it appears as if all attempts to honor Dolomieu were plagued by misunderstandings and misinterpretations of some kind.

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- Nuovo Giornale d'Italia*, Venezia, 1780, 4, No. I, 2-5 (July 24, 1779), No. II, 9-12 (July 31, 1779), No. III, 17-20 (August 7, 1779), No. IV, 25-28 (August 14, 1779), No. V, 33-37 (August 21, 1779). Whereas the ideas of Arduino on the metamorphic origin of dolomite appear scattered in different places of the above references, they were put together in a continuous and similar text (on page 22) in another of his publications, a letter sent to the paleontologist Nathanael Gottfried Leske in Leipzig entitled "Lettera orittologica del Signor Giovanni Arduino con indice dei saggi di alcune produzioni vulcaniche, minerali, e fossili inviata al celebre Signor Nathanael Godofredo Leske..." *Nuovo Giornale d'Italia*, Venezia, 1783, 7, No. II, 9-14 (July 27, 1782), No. III, 17-23 (August 3, 1782). This letter was also printed as a pamphlet entitled ARDUINO, G. (1782). *Memoria epistolare sopra varie produzioni vulcaniche minerali e fossili, del Signor Giovanni Arduino. Tratta dal Nuovo Giornale d'Italia*, Venezia, In. 12, presso Benedetto Milocco, 36 p.
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