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What is a volcano?

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ABSTRACT

The definition of a volcano is discussed, and a new encompassing version is provided. The discussion focuses on the observations that volcanism is a self-similar process that ranges many orders of magnitude in space and time scales, and that all kinds of geologic processes act on volcanoes.

Former definitions of *volcano*, such as that from the *Glossary of Geology* (1997, p. 690)—"a vent in the surface of the Earth through which magma and associated gases and ash erupt" or "the form or structure, usually conical, that is produced by the ejected material" are clearly insufficient. All definitions that we encountered tend to consider volcanoes from the point of view of a single discipline, each of them neglecting relevant aspects belonging to other disciplines. For the two cases mentioned above a volcano is seen only from the point of view of eruptive activity or of morphology.

We attempt to look at *volcano* holistically to provide a more comprehensive definition. We define a volcano as a geologic environment that, at any scale, is characterized by three elements: magma, eruption, and edifice. It is sufficient that only one of these elements is proven, as long as the others can be inferred to exist, to have existed, or to have the potential to exist in the future.

INTRODUCTION

Figure 1 shows what everyone would unquestionably call a volcano: an eruption in course. The meaning of the word *volcano* has, however, slowly changed through time. During Roman times it was the name of the god of fire (cf. Bullard, 1962; Sigurdsson, 1999), the son of Jupiter and Juno, who lived under the island now called Vulcano, in the Aeolian Archipelagos north of Sicily. Accordingly, the blacksmith work of the god Vulcano was considered the energy source for volcanic activity, whereas the eruptions were the smoke, sparks, and scoria produced during his work. The term later became used in a broad sense to indicate a mountain that throws "fire." However, it is not the etymology of the word that we are concerned with but its meaning, that is, the nature of the thing that the word *volcano* indicates. Obviously, whatever we call this thing, its actual nature and reality do not change because of our definition; rather, the definition reflects our perception and understanding of this reality. This is why an appropriate definition is so important. Accordingly, Schmincke (1986) observes that, since we do not know much about volcanoes, their definition depends strongly upon the background of the scientist giving it. Have we, in the past 20 yr, increased our knowledge about volcanoes enough that we are now able to give a more accurate definition? We would like to believe so.

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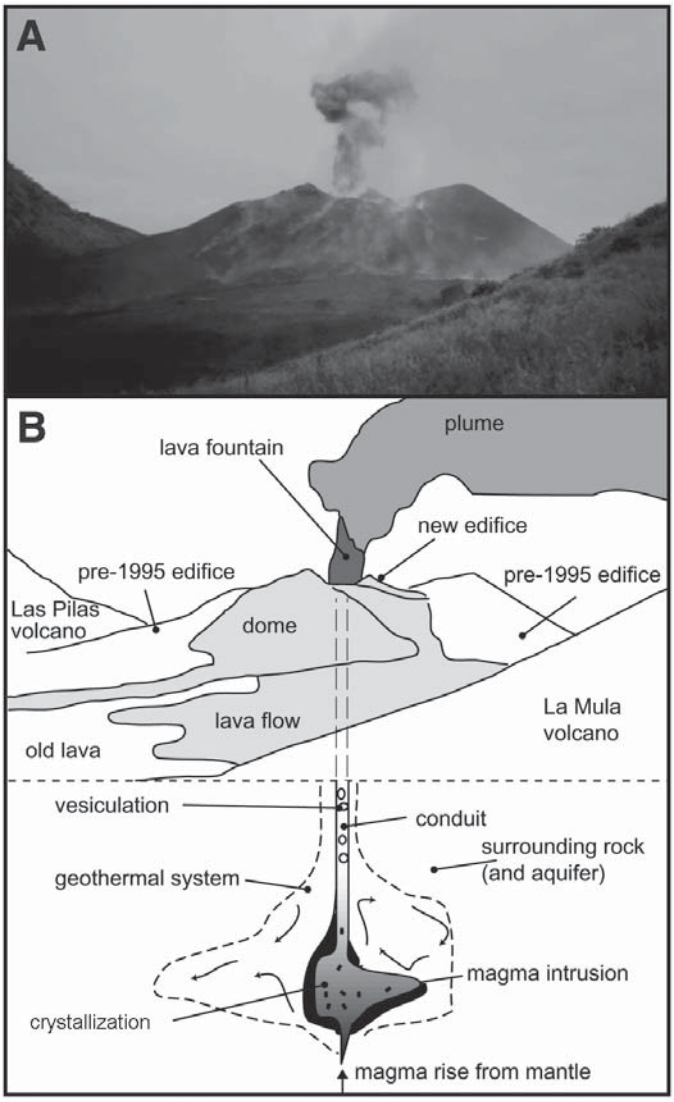

Figure 1. (A) Cerro Negro (Nicaragua) volcano during the November–December 1995 eruption. It is composed of an old cone made of scoria and lava, with a new scoria cone and lava dome growing on it. A hydrothermal system affects the style of eruptions. Volcanic material fell on the city of Leon, some 20 km away, and the gas plume extended over the Pacific Ocean. Faults formed on the cone in response to magma motion, tectonic stresses in the basement, and gravitational loading. The volcano deposits merge with those of the neighboring strato-volcanoes, forming a complex volcanic setting. (B) Sketch of Figure 1A with the "plumbing" system within the basement.

In fact, after a survey of the scientific literature about the definitions that are given to volcanoes (see Table 1), it becomes manifest that the past preference for brief definitions resulted in incomplete, limited, or sometimes contradictory and inconsistent descriptions of the complex phenomenon of volcanism. We conclude that we all probably have quite different perceptions of what volcanoes are—perceptions that, as Schmincke observed in 1986, are invariably influenced by our diverse backgrounds. This disagreement becomes particularly amplified in the corollary definitions of the words *volcanism, volcanology,* and *volcanologist.*

As we stated before, to be meaningful and useful, a definition must reflect our understanding of the nature of volcanoes, and in particular it should not exclude former definitions. Therefore, in this paper, we first analyze former definitions of the word *volcano,* pointing out facts that have become "common knowledge" but that now appear to be at odds with these definitions. Then we propose a new definition that, we think, reflects better our current understanding of volcanoes without contradicting former definitions. Of course we try to stimulate discussion by being provocative and perhaps also polemic. Thus, we expect disagreement.

Editor's note: *In the "References Cited" section at the end of this chapter, many of the alphabetical listings depart from the traditional listings by author(s) by beginning with the volume titles of encyclopedias/dictionaries, in alphabetical order, followed by the name(s) of the editor(s).*

FORMER DEFINITONS OF *VOLCANO*

Perhaps the best place from which to start in describing former definitions is the *Encyclopedia of Volcanoes* (2000; Table 1). In the more than 1400 pages of this volume, by all means a very knowledgeable volcanic tome, we cannot find an explicit proper definition of *volcano,* though in the introduction it is stated that "volcanoes and their eruptions . . . are merely the surface manifestation of the magmatic processes operating at depth in the Earth" (p. 2). On the other hand, the same *Encyclopedia* states that "Volcanology is the study of the origin and ascent of magma through the planet's mantle and crust and its eruption at the surface" (p. 2). Now, the original meaning of the term *volcanology* is the study of volcanoes. Therefore, one could infer that either volcanology has lost its original meaning or that volcanoes are the magma that rises through the planet's mantle and crust to erupt at the surface—which is certainly in contrast with what most scientists would think a volcano is. Some authors, in fact, would prefer the term *magmatology* for what the *Encyclopedia* calls *volcanology*.

What the *Encyclopedia of Volcanoes* states is analogous to the Roman myth of the god Vulcano, which focuses on the source and mechanism of volcanism more than on volcanic products, edifices, or successions; this definition has been (see, e.g., Cotton, 1944), and probably is now, accepted by many petrologists. Instead, we want to point out that the *Encyclopedia*'s definition, by itself, indicates how volcanoes are in general not very well defined and perhaps not well known. As Bullard (1962) states: "to describe what a volcano is not is much easier than to give a concise definition of what it is" (p. 8). Perhaps to avoid this problem, the *Encyclopedia of Earth System Science* (1992), in spite of the impressive erupting volcano on the cover and the numerous definitions of volcanic "things," reports no specific definition for the term *volcano,* nor for the terms volcanism or volcanology.

We have to open a parenthesis: the general understanding is that during an eruption volcanoes emplace silicate rocks. In a few

TABLE 1. COMMON DEFINITIONS OF VOLCANO, VOLCANISM, AND VOLCANOLOGY FOUND IN GEOLOGIC BOOKS, DICTIONARIES, GLOSSARIES, AND ENCYCLOPEDIAS

Year	Title	Editor/Author	Volcano	Volcanism	Volcanology
1845	Kosmos I	Humboldt	—	The essence of all the reactions of a planet against its crust and surface.	—
1858	Lehrbuch der Geognosie	Naumann	—	All the phenomena and the manifestations of forces coming from the interior of the Earth and that originate from the interaction of fluid core-rigid crust.	—
1911	Die Vulkanischen Erscheinungen der Erde	Schneider	—	The phenomena through which juvenile masses coming from deep in the Earth are transported to the interior or the surface of the crust.	—
1911	Recherches sur l'exhalaison volcanique	Brun	A place on the surface of the globe where the temperature can achieve, in a rhythmic or permanent fashion, a temperature much higher than that of the surrounding area. The temperature difference can be over 1000 °C.	—	—
1914	Der Vulkanismus	Wolff	A place at the Earth's surface where the magma and its products have come or are coming out.	All phenomena directly related to the rise of magma.	The study of the rise and the conformation of the magma.
1936 1962	Vulkane und ihre Tätigkeit	Rittmann	—	All phenomena associated with the breaking through of molten material.	The science that studies volcanism.
1944	Volcanoes as Landscape Forms	Cotton	—	The superficial manifestation of the deeper-seated processes of igneous injection or intrusion.	—
1957	Glossary of Geology and Related Sciences	Howell et al. (eds.)	**1**. A vent in the earth's crust from which molten lava, pyroclastic materials, volcanic gases, etc., issue. **2**. A mountain which has been built up by the materials ejected from the interior of the earth through a vent.	Volcanic power or activity; volcanicity. The term ordinarily includes all natural processes resulting in the formation of volcanoes, volcanic rocks, lava flows, etc.	The branch of science treating with volcanic phenomena.
1959	Geological Nomenclature	Schieferdecker (ed.)	A place at the surface of the earth where magmatic material from the depth erupts or has erupted in the past (A. Rittmann), usually forming a mountain, more or less conical in shape with a crater at the top.	All phenomena connected with the rise of magmatic material in a compact state, as injections of magma or effusion of lava, or in a dispersed state, as emanations of ejecta or gases. They are processes in and properties of the hypomagma, mainly produced by physicochemical processes in the magma itself.	The branch of science primarily treating eruptions of magma on the earth's surface, or in levels not far beneath, but also of related features in the tectonical, petrological, seismological, and geophysical fields.
1962	Volcanoes in History, in Theory, in Eruption	Bullard	A vent or chimney which connects a reservoir of molten matter known as "magma," in the depth of the crust of the earth, with the surface of the earth. The material ejected though the vent frequently accumulates around the opening, building up a cone called the "volcanic edifice."	—	The branch of science which deals with the eruption of magma upon the surface of the earth or its rise into levels near the surface.
1963	Geologisches Wörterbuch	Murawski	The construct created from the effusion and eruption of volcanic products, both on land and below the sea.	General concept indicating volcanic and subvolcanic processes.	—
1972 1980 1987 1997	Glossary of Geology	Gary et al. (eds.) Bates and Jackson (eds.) Jackson (ed.)	(**a**) A vent in the surface of the Earth through which magma and associated gases and ash erupt; also, the form or structure, usually conical, that is produced by the ejected material. (**b**) Any eruption of material, e.g., mud that resembles a magmatic volcano.	The processes by which magma and its associated gases rise into the crust and are extruded onto the Earth's surface and into the atmosphere.	The branch of geology that deals with volcanism, its causes and phenomena.
1972	Volcanoes	Macdonald	A volcano is both the place or opening from which molten rock or gas, and generally both, issue from the earth's interior onto the surface, and the hill or mountain built up around the opening by accumulation of the rock materials.	—	The science of volcanoes.

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TABLE 1. COMMON DEFINITIONS OF VOLCANO, VOLCANISM, AND VOLCANOLOGY FOUND IN GEOLOGIC BOOKS, DICTIONARIES, GLOSSARIES, AND ENCYCLOPEDIAS (*Continued*)

Year	Title	Editor/Author	Volcano	Volcanism	Volcanology
1980	Geological Nomenclature	Nijhoff (ed.)	A hill or mountain built up from the accumulation of volcanic products around a crater, i.e., the accumulation of lavas and/or pyroclastics.	The aggregate of processes associated with the surface phenomena involved in the transfer of materials from the earth's interior to or immediately below its surface.	The branch of geology that deals with volcanism, its causes and its phenomena both at the earth's surface and at deeper levels.
1984 1988 1992 1995	Dictionnaire de Géologie	Foucault and Raoult (eds.)	Place where lavas (molten magma) and hot gases reach the surface of the Earth's crust (or of the Moon, or of the planets) either on the ground or below the water. After cooling, the lavas become volcanic rocks. A volcano generally includes a volcanic cone (formed by the accumulation of the lavas and/or blocks, scoriae, and cinders) around a crater, which is the site of extrusion of the volcanic rocks brought up by the conduit.	Set of volcanic manifestations and associated phenomena.	The study of volcanoes.
1986	Vulkanismus	Schmincke	The definition is different depending on the background of the scientist giving it.	—	—
1987	Grand Larousse		Relief, in general, of conical shape, formed by magmatic products, which reach the surface of the earth in the air or under water.	—	—
1992	Dictionary of Science and Technology	Morris (ed.)	1. A vent or fissure in the earth's surface through which magma and its associated materials are expelled. 2. The generally conical structure formed by the expelled material.	Any of the processes in which magma and its associated gases rise up from the earth's interior and are discharged onto the surface and into the atmosphere.	The study of the causes and phenomena associated with volcanism.
1992	Encyclopedia of Earth System Science	Nierenberg (ed.)	Volcanoes are the landforms that are made when magma (molten rock) erupts onto the surface of the earth.	—	—
1993	The Encyclopedia of the Solid Earth Sciences	Kearey et al. (eds.)	—	—	—
1993	Volcanoes: A Planetary Perspective	Francis	A site at which material reaches the surface of the planet from the interior.	The manifestation at the surface of a planet or satellite of internal thermal processes through the emission at the surface of solid, liquid, or gaseous products.	—
1994	Volcanoes: An Introduction	Scarth	A volcano is usually a cone-shaped hill or mountain composed of materials erupted through an opening in the Earth's crust which extends from the hotter zone below.	—	—
1996	L'Etna et le monde des volcans	Tanguy and Patanè	A volcano is the edifice built by the accumulation of tephra falls and lava flows emplaced by eruptions that have been concentrated in the same place of weakness of the earth's crust.	—	—
1996	Vulcani e Terremoti	Casertano	A fracture on the Earth's crust through which the magma passes from the Earth's interior to its surface. The mountain (usually conical) that forms around and above the fracture owing to the accumulation of the emitted materials.	The set of phenomena and manifestations more or less directly related to the magmatic activity. Volcanism is not equivalent to magmatism.	

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TABLE 1. COMMON DEFINITIONS OF VOLCANO, VOLCANISM, AND VOLCANOLOGY FOUND IN GEOLOGIC BOOKS, DICTIONARIES, GLOSSARIES, AND ENCYCLOPEDIAS (*Continued*)

	Title	Editor/Author	Volcano	Volcanism	Volcanology
2000	Encyclopedia of Volcanoes	Sigurdsson et al. (eds.)	Volcanoes and their eruptions … are merely the surface manifestation of the magmatic processes operating at depth in the Earth.	—	Volcanology is the study of the origin and ascent of magma through the planet's mantle and crust and its eruption at the surface. Volcanology deals with the physical and chemical evolution of magmas, their transport and eruption, and the formation of volcanic deposits at the planetary surface.
2000 to 2008	This work		A volcano is a geologic environment that, at any scale, is characterized by three linked elements: magma, eruption, and edifice. It is sufficient that only one of these elements is proven, as long as the others are inferred to exist, to have existed, or to have the potential to exist.	The set of processes associated with a volcano.	The study of volcanoes.

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cases these rocks can be carbonatitic (as Oldoynio Lengai in Tanzania; cf. Le Bas, 1977), sulfuric (as on Io; Lopes-Gautier, 2000), icy (as on the icy satellite and Triton; Geissler, 2000), clayey (as in many terrestrial mud volcanoes; Macdonald, 1972), or of just about any kind of rocks (as in many terrestial phreatic or hydrothermal explosions with no direct involvement of magma; cf. Macdonald, 1972). Also in these cases the word *volcano* is used, adding immediately before, the kind of erupted material (e.g., mud volcano).

Surprisingly, an eruption may create no volcanic edifice, in the hypothetical case of the erupted material being completely dispersed in the atmosphere and/or rapidly eroded away. This is why, perhaps, the classic definition of volcano remains general (*Glossary of Geology,* 1997, p. 690): "(a) a vent in the surface of the Earth through which magma and associated gases and ash erupt; also, the form or structure, usually conical, that is produced by the ejected material; (b) any eruption of material that resembles a magmatic *[sic!]* volcano."

In fact, the much older definition from *Geological Nomenclature* (1959) may, by intuition, seem more adequate to many geologists: "a place at the surface of the earth where magmatic material from depth erupts or has erupted in the past, usually forming a mountain, more or less conical in shape with a crater at the top" (p. 223). Note that (in contrast to the definition given just above) here the crater, equivalent to the vent, is the last feature to appear, as if it is not so essential. A more recent edition of the same dictionary reports a definition of *volcano* that makes no explicit mention of magma or eruptions (*Geological Nomenclature,* 1980, p. 106): "a hill or mountain built up from the accumulation of volcanic *[sic!]* products around a crater, i.e. the accumulation of lava and/or pyroclastics."

A definition that is a combination of the former ones is given by the *Dictionnaire de Géologie* (1995): "a place where lavas, molten *[sic!]* magma, and hot gas reach the surface of the Earth's crust (or that of the moon, or of a planet) either in the air or below the water. By cooling, these lavas give volcanic (or effusive) rocks. A volcano generally includes a volcanic cone (the accumulation of lavas and/or blocks, scorias and ash) surrounding a crater, which is the place of exit of the volcanic rocks *[sic!]* that rise through the conduit."

We could spend much longer presenting the quite varied set of definitions published in the scientific literature (Table 1). As can be easily seen, all these definitions maintain some degree of inaccuracy and dependence on the background of their authors. Given the substantial increase in knowledge about volcanoes that has been achieved during the past decades, we believe that these definitions tend to be now inadequate and need some form of integration. Indeed, a volcano is far more complex than what is implied by each of the definitions.

GENERAL OBSERVATIONS ON FORMER DEFINITIONS

The definitions in the scientific literature fall, in general, between three end-member headings: rising magma (cf. Schneider, 1911; Bullard, 1962; *Encyclopedia of Volcanoes,* 2000), eruptions (cf. Wolff, 1914; *Glossary of Geology and Related Sciences,* 1957; *Glossary of Geology,* 1997; Francis, 1993), and volcanic edifice (cf. *Geologisches Wörterbuch,* 1963; *Geological Nomenclature,* 1980; Tanguy and Patanè, 1996). Obviously, petrologists will tend to like the definitions that focus on the magma, geophysicists the ones that focus attention on the eruption, and structural geologists and stratigraphers the ones centering on the edifice or the deposits in general; other specialists will endorse definitions somewhere in between. This is why, in addition to some internal inconsistencies, all definitions appear to be generally unsatisfactory.

Even the simple, early definition of Brun (1911) that a volcano is a *hot spot* obviously misses some major aspects. Indeed, our perception is that mass and momentum transport in a volcano are as important as transport of thermal energy.

For instance, to criticize the most common definition of volcano reported above (*Glossary of Geology,* 1997), one may observe that the first part of the definition should include the feeding conduit in addition to the vent, and possibly the eruptive plume as well. In addition, to be polemic, the use of the words "surface of the Earth" excludes most terrestrial volcanoes that form below sea level or beneath glaciers (making them intrusions) and all planetary volcanoes, which are not terrestrial! Also, a vent formed during a phreatic eruption, which by definition has no magma, could not be considered a volcano. For the second part of the same definition, all "volcanic" intrusive bodies are excluded, such as dikes, sills, magma chambers, and cumulate complexes. In addition, are the volcanic deposits that remain after erosion has taken away parts of the original edifice still to be called a volcano? Also, are the volcanic deposits produced by the various kinds of edifice collapse still part of the volcano?

Another major deficiency of this and all other definitions is that they ignore the hydrothermal systems, which are an integral part of all volcanoes (at least on Earth). In fact, all books on volcanoes include chapters on the hydrothermal system (cf. Macdonald, 1972; *Encyclopedia of Volcanoes,* 2000). In addition, are the non-eruptive volcanic processes, such as volcanic spreading (cf. Borgia et al., 2000a) and the interaction between volcanic edifice stability and basement tectonics (Lagmay et al., 2000; Tibaldi, 2005) part of the dynamics of volcanoes?

Even if we accept standard definitions, more problems arise in defining simple geometric parameters of volcanoes: how is the volcano radius or height measured? Is the radius measured to a basal arbitrary break in slope, to the edge of the lava fields, or to the distance at which volcanic deposits remain continuous? According to the standard definition of *volcano* the radius should be to the edge of the ejected deposits, which usually is time dependent and far beyond the distance of any "reasonable" radius. In the extreme, a volcano that erupts deposits over the whole surface of the Earth has the shape of a spherical shell, not that of a cone!

How is the height of volcanoes measured? Is it the thickness of the volcanic pile, and if so, where is the lower boundary? Is it measured from the level of the basement rocks, which

"hopefully" are non-volcanic, or is the feeding conduit included also? What about volcanoes that overlap, such as in Hawaii? Here the height of each single volcano is practically impossible to determine. Not surprisingly, *Volcanoes of the World* (Simkin et al., 1981) reports no dimensions for the listed volcanoes.

A PROPOSED NEW DEFINITION

Before we propose what we think volcanoes are, we would like the reader to ponder two other aspects of volcanoes, which are usually not stressed enough. First, consider the diversity of geologic processes. Clearly, *all processes, properly scaled down, in addition to volcanism, occur on volcanoes:* from chemical and clastic sedimentation to erosion, from dynamo-thermal metamorphism to rock-water interaction, from earthquakes to giant landslides, from volcano-basement interaction to regional geodynamics controlling volcano structural evolution, from death to life. No other geologic environment is so inclusive.

Second, consider the aspect of scale. Large volcanoes, Etna for instance, are commonly made of the superposition of volcanic cones (the "Concazze" and "Il Piano" centers that are the most recent, among the many others; Calvari et al., 1994). These, in turn, have smaller cones on their edifice (like the "cratere di nordest" or the "cratere centrale"; Chester et al., 1985) on which are the actual eruptive boccas. In fact, volcanoes range in size over at least 4–5 orders of magnitude, from meters to hundreds of kilometers, the largest volcanoes always including smaller ones. Their life span may range from hours to millions of years. In addition, as volcanoes grow in size, they tend to change from the generally asymmetric single volcanic deposits, to the radial symmetry of stable scoria cones, to the pseudoradial symmetry of small spreading stratocones like Concepción (Borgia and Van Wyk de Vries, 2003) or Etna (Borgia et al., 1992), to the bilateral symmetry of the large, spreading shield volcanoes like Kilauea (Hill and Zucca, 1987).

In this view, the leap forward in scale to spreading mid-ocean ridges should not be unexpected, and it is intriguing (Borgia and Treves, 1992). Indeed, all of the definitions of *volcano* given in Table 1 apply to mid-ocean ridges as well. They are simply very large volcanoes, so large and massive that gravitational pressure overcomes the rock strength at their base (in the asthenosphere), making them relatively "flat" sectors of spherical shells. Volcanoes of that mass could have only that shape. This fact should not disturb us: There is more difference in size between a scoria cone and Mauna Loa than between Mauna Loa and a mid-ocean ridge. Indeed, the stratigraphy, structure, and processes occurring in the Hawaiian rift zones are frequently compared to those of mid-ocean ridges (cf. Hill and Zucca, 1987; Borgia and Treves, 1992). A similar relationship between volcanism and tectonics at planetary scale may also hold for Mars and Venus (Borgia et al., 2000b; Borgia and Murray, this volume) and for the asteroid volcanism, which generally involves the whole body (Wilson and Keil, 1996).

Indeed, T.A. Jaggar and A. Rittmann considered volcanism ubiquitous within and beneath the Earth's crust (Rittmann, 1936). In a quite figurative fashion, A. von Humboldt (1845) viewed volcanism as "the essence of all the reactions of a planet against its crust and surface," an opinion shared also by Naumann (1858). Similarly, we think that the Earth itself may be considered a self-organizing, self-stratified giant volcano (H. Shaw, 1995, written commun.), so big and so weak that the gravitational pressure collapses it into an orbiting "spherical" planet (Borgia, 1994). We remark that this statement is nonexclusive; other disciplines may have a similar claim without weakening our proposal. It is no surprise, then, that all the geologic processes that occur on a planet are found, properly scaled, at the size of each volcano. Small scoria cones and planets are the volume end members of the same general process: the interaction and feedback between gravitational, thermal, and chemical fields on matter. We observe that, up to now, the cutoff between these two end members has been too drastic. As usual, we may well benefit from dropping our old, textbook ideas.

In view of the above, we are forced to accept that volcanoes are not simple geologic "objects" like crystals, strata, faults, or fossils. Indeed, they are analogous to complex geologic environments, perhaps like sedimentary basins or orogens. Thus, we need a definition that will tend to stress a context much broader than the usual one. Accordingly, we propose that

> Volcanoes are geologic environments where magma, generated at a source within the crust or mantle, flows upward and is subject to varying amounts of physicochemical evolution, intruding and reacting with the encasing rocks and other magma, and originating a geothermal system. Once near the lithosphere top (that is, of a major rigid-fluid, high-low density zone of interface) the magma erupts, piercing the interface. Volcanic deposits are accumulated from eruptions giving rise to a volcanic edifice. In turn, these deposits may become intruded or modified by magma, eruptions, geothermal fluids, tectonics, erosion, landsliding, and all other kinds of geologic processes. The boundaries of this environment (volcano) are frequently time dependent, transitional, ill-defined, or unknown. However, working boundaries can be based on different arguments using factors such as geometry, morphology, and structure.

Of course, we would like a less baroque and more down-to-earth definition. Therefore, we may state in short that

> A volcano is a geologic environment that, at any scale, is characterized by three linked elements: magma, eruptions, and edifice.

It is sufficient that only one of these elements is proven, as long as the others are inferred to exist, to have existed, or to have the potential to exist. Here we use the word *edifice* to indicate all the various geomorphic expressions of volcanoes, including negative features such as calderas and maars.

These definitions may be easily applied to "volcanoes" made by materials different from magma, such as sulfur, ice, mud, and in principle any fluid, only if a direct analogy between them and

"magmatic" volcanoes is acceptable. In this case a more general definition can be easily obtained just by substituting, in the short definition above, the word *fluid* to the word *magma*. Consequently, we think that the corollary definitions of *volcanism* as the set of volcanic processes, and *volcanology* as the study of volcanoes, may still be considered quite adequate.

CONCLUSIONS

We realize that the new definition of *volcano* may require adjustment after broader discussion. However, we think that it is now closer to what volcanoes really are: highly complex geologic environments. It stresses the fact that volcanoes belong to a wide range of scales in time and space and that they are dynamic environments—not systems, which have well-defined boundaries—where all kinds of geologic processes act on the rising magmas, the eruptions, the volcanic edifices, and their basements. Therefore, a volcano cannot be limited to the volcanic edifice proper, but must include its basement at least up to where volcanic processes, such as (but not limited to) intrusions, geothermal activity, metamorphism, and edifice-basement tectonic interactions, occur in it. Obviously, our definition does not require unique (rigid) geometric boundaries, which will be better defined on the basis of the studies conducted for specific volcanoes.

This definition has one other important consequence: all geologic disciplines should be applied to and integrated in the study of volcanoes. Therefore, sarcastically, since volcanoes (volcanic environments) may extend to planetary scales, *volcanology,* as it is thought of today, should not exist as an independent discipline because it is only a scaled down *geology*. Inversely, and we are certainly biased toward this view, geology could simply be called *volcanology,* so that volcanologists could continue to exist!

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