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FORUM CONTRIBUTION

Translations of volcanological terms: cross-cultural standards for teaching, communication, and reporting

Andrew J. L. Harris[1] · Alexander Belousov[2] · Sonia Calvari[3] · Hugo Delgado-Granados[4] · Matthias Hort[5] · Ken Koga[1] · Estuning Tyas Wulan Mei[6] · Agung Harijoko[6] · José Pacheco[7] · Jean-Marie Prival[1] · Carmen Solana[8] · Þorvaldur Þórðarson[9] · Jean-Claude Thouret[1] · Benjamin van Wyk de Vries[1]

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Abstract When teaching at a non-English language university, we often argue that because English is the international language, students need to become familiar with English terms, even if the bulk of the class is in the native language. However, to make the meaning of the terms clear, a translation into the native language is always useful. Correct translation of terminology is even more crucial for emergency managers and decision makers who can be confronted with a confusing and inconsistently applied mix of terminology. Thus, it is imperative to have a translation that appropriately converts the meaning of a term, while being grammatically and lexicologically correct, before the need for use. If terms are not consistently defined across all languages following industry standards and norms, what one person believes to be a *dog*, to another is a *cat*. However, definitions and translations of English scientific and technical terms are not always available, and language is constantly evolving. We live and work in an international world where English is the common language of multi-cultural exchange. As a result, while finding the correct translation can be difficult because we are too used to the English language terms, translated equivalents that are available may not have been through the peer review process. We have explored this issue by discussing grammatically and lexicologically correct French, German, Icelandic, Indonesian, Italian, Portuguese, Russian, Spanish, and Japanese versions for terms involved in communicating effusive eruption intensity.

Keywords Volcanology · Communication · Teaching · Translation

Introduction

Due to the needs of internationalization and globalization in science and education (e.g., Knight 1994; Gacel-Ávila 2005), a lack of peer-reviewed, industry-standard term translation of formal nomenclature is becoming an increasing problem. This

Editorial responsibility: P-S Ross

✉ Andrew J. L. Harris
a.harris@opgc.univ-bpclermont.fr

[1] CNRS, OPGC et IRD, Université Clermont Auvergne, Campus Les Cézeaux, 6 avenue Blaise Pascal, Aubière 63178, France

[2] Institute of Volcanology and Seismology, Piip Boulevard 9, Petropavlovsk-Kamchatsky, Russia 683006

[3] Istituto Nazionale di Geofisica e Vulcanologia Sezione di Catania (INGV-Catania), Piazza Roma 2, 95125 Catania, Italia

[4] Departamento de Vulcanología, Instituto de Geofísica, Universidad Nacional Autónoma de México, CU, Coyoacán, 04510 Mexico City, Mexico

[5] Institut für Geophysik, Universität Hamburg, Bundesstrasse 55, D-20146 Hamburg, Germany

[6] Faculty of Geography, Universitas Gadjah Mada, Yogyakarta 55281, Indonesia

[7] Edifício do Complexo Científico, Instituto de Investigação em Vulcanologia e Avaliação de Riscos/Universidade dos Açores, Rua da Mãe de Deus, 3° Andar—Ala Sul, 9500-321 Ponta Delgada, Açores, Portugal

[8] School of Earth and Environmental Sciences, University of Portsmouth, Burnaby Building, Portsmouth PO1 3QL, UK

[9] School of Engineering and Natural Sciences—Faculty of Earth Sciences, University of Iceland, Askja/N-141, 101, Reykjavik, Iceland

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is especially true for teaching and outreach in non-English speaking countries, where translation of modern terms that only appear in the English literature is required. Such a need is recognized through the publication of documents such as the English–Spanish translation list for common terms in volcanology and petrology as drafted by the Geological Society of Mexico (Sociedad Geológica Mexicana 2016). Given internationalization of teaching, research, and communication, the French Education Ministry recently posted advice to teachers on French–English and English–French translations of international education terminology, so as to take into account the proliferation of modern English language teaching terms (JORF 2017). These are just two examples of English translation advice currently being disseminated to aid the internationalization process in universities and research institutes spanning Germany, Iceland, Indonesian, Italy, Portugal, Russia, and Japan, whereas English speaking countries already have well-established and comprehensive guidelines for appropriate phraseology (e.g., Hansen 1991).

The problem

Experiences from an international volcanology course taught since 2011 in Mexico and open to all Latin-American countries, illustrated the three main linguistic problems facing us today. First, an English technical term may not exist in translated form. Indeed, we have found that even non-English mother tongue specialists, used to dealing with English terminology, express a difficulty when asked to translate a term into their own language, because they are so used to the English term. Second, some terms may have multiple translation options. For example, *hazard* has no translation in Spanish and hence two alternative words, "peligro" (danger) and "amenaza" (threat), have been used and inconsistency in usage of the two terms causes confusion. Third, multiple terms—that have different meanings in English—may only be expressed by one word in another language. For example, *welding* and *sintering* have only one word in Spanish "soldamiento."

Translation of effusion rate terms

Given the linguistic nuances of different languages and differences in alphabets and lexicology across the globe, literal translations of terms will rarely be appropriate. To explore translation problems and to begin to refine a blueprint for multi-lingual transfer of key terms in volcanology, we explored the problems involved in translation of a terminology system which is very much based on an English nomenclature and which does not currently take into account other linguistic needs. Our test, which originated from a request for translation of volcanological terms into French for a dissertation, soon revealed that many international colleagues were facing similar problems, and a discussion grew homing in on common issues faced by all languages when translating a new term from English. The test was based on the fourfold terminology scheme to define and standardize descriptions of the intensity (in m^3/s) of effusive eruptions (Harris et al. 2007). The initial scheme was set up due to problems encountered when lava volume flux values, averaged over different time periods or spatial scales, or measured using different approaches, were compared. Terms were used interchangeably for different temporal scales, so that a degree of standardization was required. The terms and definitions were set up as follows:

1. *Instantaneous effusion rate* (IER): The volume flux of erupted lava that is feeding flow at any point in time (Walker 1973).
2. *Time averaged discharge rate* (TADR): The volume of lava erupted over a given time period, so that the discharge is averaged over a known time period (Lipman and Banks 1987).
3. *Eruption rate* (ER): The total volume of lava emplaced since the beginning of the eruption, divided by the time since the eruption began. The measurement thus uses the cumulative volume curve to obtain the volume flux to estimate the volume flux required to generate the volume at the chosen point in time (Harris et al. 2000).
4. *Mean output rate* (MOR): Is the total volume erupted during the entire eruption divided by the duration of the eruption (Barberi et al. 1993).

The test involved setting up a multicultural, multi-linguistic, and multidisciplinary forum to identify and solve problems in translation and communication through discussion of appropriate equivalents in French, Spanish, German, Italian, Icelandic, Indonesian, Russian, and Japanese. The resulting translation system is given in Table 1, and the key points of what turned out to be a lively and productive debate among the group are reported here. Also, given as footnotes to Table 1, are the thought processes implemented by each translator, which is given to illustrate issues that need to be considered and resolved, when implementing translations of volcanological terms.

Discussion

Because many modern classification schemes only appear in English, students in non-English speaking countries need to become familiar with English-based terminology. However, there will also be occasions when a term needs to be translated for effective verbal or written communication. This may be true for students, researchers, teachers, hazard managers, crisis responders, laypeople, and tourist guides alike. Anyone, that is, who needs to speak and communicate science. Thus, to

Table 1 Translation table for effusive eruption intensity terms with translator explanation notes

English	French (Note 1)	Spanish (Note 2)	Italian (Note 3)	Russian (Note 4)	Japanese (Note 5)	Indonesian (Note 6)	Icelandic (Note 7)	Portuguese (Note 8)	German (Note 9)
Instantaneous effusion rate	Taux d'émission instantané (or) débit[a]	Tasa de efusión instantánea	Tasso Effusivo Istantaneo (or) portata[a]	Мгновенный расход лавы	shun-kan-fu-n-shu--tsu-li-tsu (瞬間噴出率)	Laju efusi seketika	Tafarlaust streymi	Taxa de efusão instantân-ea	momentane Effusionsrate
Time averaged discharge rate	Débit temporel moyen	Tasa de descarga temporal promedio	Tasso Effusivo Medio (or) portata media	Средний расход лавы	Ji-kan-he-i-kin-fu-n--shu-tsu-li-tsu (時間平均噴出率、単位時間あたりの平均噴出率)	Laju debit per waktu	Tímavegið meðalstreymi	Média temporal do Débito	zeitlich gemittelte Effusionsrate
Eruption rate	Taux d'émission total (or) débit total	Tasa de erupción	Tasso dell'Eruzione	Средний расход лавы с начала извержения	se-ki-san-fu-n-shu--tsu-ri-tsu (積算噴出率)	Laju erupsi	Kvikuflæði	Débito acumula-do	mittlere Effusionsrate seit Eruptionsbeginn
Mean Output rate	Flux eruptif moyen (or) débit moyen	Tasa promedio de salida	Tasso di Emissione Medio	Средний расход лавы за время всего извержения	he-i-kin-fu-n-shu--tsu-li-tsu (平均噴出率)	Laju luaran rerata (or) laju luaran rata-rata	Meðalframleiðni (á tímaeiningu)	Débito médio da erupção	Eruptionsrate gemittelt über die gesamte Eruptionsdauer

[a] In French, "débit" is an instantaneous measure (volume of lava/time measured at time t_0); so we can say "débit" as well as "taux d'émission instantané"; the same applies to "portata" in Italian

Notes:

(1) The literal translation of *effusion rate* would be "taux d'effusion." However, in French *effusion* tends to be reserved to describe feelings, "effusion de sentiments" for example. The term "taux d'émission" is thus more appropriate because, in French, a lava flow is *emitted* (i.e., "émise") with the word "instantané" (instantaneous) added because it is a measure at a specific point in time—although it should be said that "débit" (volume per unit of time) is always instantaneous. For time-averaged values, use of the French word "débit" is thus appropriate, this being the closest equivalent to *discharge*. To stress the *time* "temporal" and *averaged* "moyenné" nature of this time-averaged value, we thus arrive at "débit temporel moyen." For mean output rate use of the term "flux éruptif moyen" likewise highlights that the flux is an average "moyen," but now for the entire *eruptive* "éruptif" duration, rather than a period within it, is considered; where grammar rules dictate that we need to switch the words *eruptive* and *flux* so that the phrase becomes "flux éruptif." In French, though, *flux* is not usually used for fluids, for example we would say "un flux de voitures" (a flow of cars), so we say "un débit de lave" in the sense of output rate of lava at time t_0.

(2a) When many countries share the same language, the case of TADR-translation illustrates very well how different the usage of a language can be from country to country. For example, in some Latin-American countries, TADR could be translated as "Tasa de Descarga Temporal Promedio," but other linguistic preferences may be "Tasa de Caudal Temporal Promedio." In these cases, some would argue that "caudal" would be good for *discharge* of Newtonian fluids. In addition, as in French, in Spanish the word "efusivo" is reserved for someone with a hearty, warm character. However, some volcanologists in Spain and Latin-American countries have begun to use the term in the English sense to imply *effusive*, as well as "efusión" for *effusion* (Aurand 2011). In Spanish-speaking countries subject to volcanic hazard, most people are now familiar with the term (the meaning having been explained by hazard managers and volcanologists). However, "emisión" would be the most correct term. For *mean output rate*, "tasa de salida promedio" or "tasa promedio de salida" is used in Mexico. However, in Spain, the term "promedio" is not used commonly. Instead, "media" is used to imply a mathematical average; "media" being a false friend for English speakers. Interestingly, both average and mean translate both as "media" (or "promedio"). Given that *average* would best translate as "media" and mean as "promedio," but that both refer to the same concept coupled with the problem of the false friend effect of "media," "promedio" may be the best option. In the case of *eruption rate*, the term "tasa de erupción" would be the obvious direct translation. However, direct use of the term *flux* is not appropriate because in technical Spanish the direct equivalent, "flujo," indicates that the cross section or shape of a conduit or channel is well known. Thus, in this case, *eruption flux* cannot be translated to "flujo eruptivo," but instead "tasa eruptiva" or "tasa de emision" would be correct.

(2b) The word "descarga" has several meanings in the dictionary of the Spanish academy of language, which also vary between countries:

1. f. Acción y efecto de descargar.

(action and effect of unloading)

2. f. descarga cerrada.- f. Mil. Fuego que se hace de una vez por uno o más batallones, compañías, secciones, etc.

(military term for coordinated firing of weapons)

3. f. Pérdida de carga eléctrica.

(electrical discharge)

4. f. Arq. Aligeramiento de un cuerpo de construcción cuando se teme que su excesivo peso la arruine.

(In architecture, lightening of a heavy construction body to avoid damage)

5. f. Cuba y Ven. reprensión (acción de reprender).

(In Cuba and Venezuela: to tell off or to make an outburst in anger)

6. f. Cuba. Actuación musical, espontánea o programada, de uno o varios artistas ante un público reducido.

(Cuba: musical show)

(3) The literal translation of *effusion rate* in Italian is "tasso effusivo," with "tasso" translating the word *rate* and "effusivo" the term *effusion*. Thus, *Instantaneous Effusion Rate* becomes "Tasso Effusivo Istantaneo." However, two textbooks on volcanology used in the Italian universities are those of Scandone and Giacomelli (1998) and Barberi et al. (2005). Here, when dealing with effusion rate, the authors use the term "tasso di emissione," adding "di magma" (of magma) to specify that they are referring to magma. In fact, the term "emissione" in Italian means just something that is *coming out* or *being emitted*, thus it is not strictly related to lava, but is instead a very general term which is applicable to virtually anything, either fluid or solid, that issues forth or is transmitted. If we make a comparison with the terms used in hydraulics for the amount of water that exits from a pipe, then the term "portata" is probably more appropriate. "Portata" means *flow rate* and refers to the amount of fluid passing through a pipe, conduit or vent per unit time, and refers to something fluid enough to flow. The term "portata" was used, for example, by Cavallaro (1957) when describing the decrease in effusive activity at Stromboli during the 1956 eruption and is used also in the textbook of Barberi et al. (2005) where the term is synonymous with effusion rate. Thus "tasso effusivo" or "portata" are synonymous with effusion rate, and we can use "istantaneo" (instantaneous) to specify that the value refers to the exact moment when it was measured. When dealing with *time-averaged discharge rate*, we cannot use a literal translation of discharge, which in Italian is "discarica," because this is not a verb but a noun which indicates rubbish storage or a garbage dump. In this case, we may thus consider adding "medio" (time-averaged) to the previous term, so that TADR becomes "Tasso Effusivo Medio" or "Portata Media." For *eruption rate*, the literal translation in Italian is "tasso eruttivo." However, in Italian "tasso eruttivo" and "tasso effusivo" are often considered to be synonymous, although the word "eruttivo" is more generic and is applicable to both solid particles erupted explosively and emission of molten lava, whereas "effusivo" can be applied only to molten material (lava), but not to pyroclastics. Thus, to avoid any misunderstanding, it would be better to specify "Tasso dell'Eruzione," to mean that the rate considered is time-averaged since the beginning of the eruption. Finally, when considering *mean output rate*, we can simply use the literal translation "Tasso di Emissione Medio," which is similar to the French counterpart. Unfortunately, we also note that "tasso" in Italian also means badger so that if taken out of context a *small flux* ("un piccolo tasso") could be taken to mean *a small badger*. An important point to make here is that there is often a need to distinguish between flow- and dome-forming events by using the term *effusion* for the former and *extrusion* for the latter. Hence, the words *effusion* and *extrusion* become switched depending on eruption type (Harris et al. 2007). Thus, in the Italian literature, while the word "effusione" (effusion) is used for emission of fluid lavas (lava flows), and "estrusione" (extrusion) is used for eruption of highly viscous lavas (domes).

(4) In the Russian volcanological literature the general term to denote discharge rate of lava is "Расход лавы" (Fedotov et al. 1984; Dvigalo et al. 2014). If used strictly in this form without indication of the measured time period, it corresponds to instantaneous effusion rate (the term "Мгновенный расход" adopted from Russian hydrogeology can be also appropriate). However, "Мгновенный расход лавы" (although not yet used in Russian volcanological literature) is probably a better fit. The term "Средний расход лавы" (as well as its modification "Осреднённый расход лавы") corresponds to *time-averaged discharge rate*. Instead, *eruption rate* and *mean output rate* have no specific equivalents in the Russian literature. However, we can use *time-averaged discharge rate* ("Средний расход лавы") with an indication of the measured time period added. Thus, eruption rate becomes "Средний расход лавы с начала извержения," i.e., the time-averaged discharge rate since the beginning of the eruption and mean output rate becomes "Средний расход лавы за время всего извержения," i.e., the time-averaged discharge rate during the entire eruption. We note, though, as in French, use of the word "дебит" (débit or output) instead of "расход" (rate) can also be appropriate. An important point to make here is that there is often a need to distinguish between flow- and dome-forming events by using the term *effusion* for the former and *extrusion* for the latter. Hence, as in Italian, the words *effusion* and *extrusion* become switched depending on eruption type. Thus, in the Russian literature, while the word "эффузия" (effusion) is used for emission of fluid lavas (lava flows), "экструзия" (extrusion) is used only for eruption of highly viscous lavas (domes). We note that, in the past, the Russian word "дебит" (debit) has been used as an equivalent for discharge. This term is widely used in Russian hydrogeology to describe discharge of water springs and artificial wells and has been used on a few occasions to describe lava issuing from a vent.

(5) For the word approximately corresponding to *eruption* with a specific reference to a dynamic state at which gas, fluid, and/or solids are emitted, Japanese volcanological literature (e.g., Fujii et al. 1988; Koyaguchi 1995; Nakada et al. 2001) primarily uses the term "fu-n-shu-tsu" (噴出), where the "n" sound rhymes with *done*. It should be noted that a commonly used Japanese word for *eruption*, "fu-n-ka" (噴火), is generally used to describe the state of a volcano rather than the physical phenomenon of material flow. Translated words corresponding to *effusion* (流出), *discharge* (放出), and *output* (出力、放出), are seldom used in the Japanese literature. The word, "li-tsu" (率), where pronunciation of "li" is close to the first syllable of liquor, is added to signify rate. Finally, a scientific term is often constructed by a sequence of attached words, somewhat similar to German, such that "fu-n-shu-tsu-li-tsu" (噴出率) now becomes eruption rate, for example. The word *magma* (マグマ、溶岩) can be added to clarify the nature of eruption rate. In general, the Japanese volcanological literature uses the term "fu-n-shu-tsu-li-tsu" (噴出率) for an eruption rate, as taken from the terminology used to describe the so-called step diagram of Koyama and Yoshida (1994), in which the cumulative eruption mass is plotted against time. Often the term itself is not sufficiently precise to articulate the time duration over which an eruption rate is averaged. Further precision would thus be desirable to articulate the significance of numerator (volume or mass) and denominator (time period). This could be achieved by adding more terms indicating the nature of calculation. Use of ideograms, kanji characters (or Chinese characters adapted in Japan during the seventh and eighth centuries), normally aid in articulating scientific terms without

creating excessively long words in Japanese. Therefore, use of acronyms derived from the Japanese language is essentially non-existent in science. However, there are several geoscience terms for which the English-derived acronyms are applied as-is, i.e., in their English (non-translated) alphabet form, which in this case would be IER, TADR, ER, or MOR.

(6) Bahasa Indonesia is the official language of Indonesia. Bahasa Indonesian has many "loan words" that are adopted from several languages, but with different pronunciation and/or spelling as that in the original language. Loan words are very common in Bahasa Indonesia for scientific purposes, where the loans are mainly from English and Latin words. The word "erupsi" is one example of loan word that is modified from the English word *eruption*, where we mutate here to "efusi" for *effusive*. Bahasa Indonesia also has the word "letusan," which means *eruption*, but "letusan" has a very broad scope that has close association with *explosion*, *burst*, and *blast* and which can have many other applications. The word "erupsi," though, is reserved for volcanic activity. Thus, to translate *instantaneous effusion rate*, we use "laju efusi seketika," in which "laju" may be used as an adjective for *rapid*, *swift* or *fast*, but which may also be used as noun (*rate* or *speed*). Because effusion rate is measured at a specific point in time, therefore the word "seketika" (*momentary*) needs to be added, so that we arrive at "Laju efusi seketika." The term *time-averaged discharge rate* is translated as "laju debit per waktu," taking now "debit" from French and *per* from English, with "waktu" meaning a *temporal period*. We note here that, although 'pelepasan' is generally used for *discharge*, in the scientific sense "debit" has been adopted. *Mean output rate* is translated to "laju luaran rerata," or "laju luaran rata-rata," because we can use both the words "rerata" and "rata-rata" for the equivalent of *mean*.

(7) The Icelandic terms had to be constructed from scratch, because no equivalent system exists in Icelandic. In Thordarson (2013), for example, "framleiðni" (*productivity*) is used for both what Rowland and Walker (1990) define as time-averaged discharge rate and for what Walker (1973) defined as mean output rate so that, in these cases, there is just a single word ("framleiðni") for all four terms. Thus *instantaneous effusion rate* was constructed from "streymi" for flux or rate of flow and "augnablik" which translates as *that moment*, i.e., something that is occurring in an instance, to give "augnabliks streymi." For time-averaged discharge rate, "meðalstreymi" can now be used for *average flux* or *average discharg*e, and "tímavegið" for *time-averaged*, so that we arrive at "tímavegið meðalstreymi." For *Eruption Rate*, "Kvikuflæði" translates as *flow of magma or magma flow rate*, with "Flæði" being the equivalent of "streymi" (i.e., flow). Here "kviku" is drawn from the word "kvika" which means magma, so that the word Kvikuflæði is built. Finally, *mean output rate* can be translated to "Meðalframleiðni (á tímaeiningu)" where "Meðal" is Icelandic for average or mean and "framleiðni" means productivity, so that the qualifier "á tímaeiningu" is added to stress *(per unit time)*.

(8) The word "efusivo" has different meanings in the Portuguese language, but is already listed in the dictionary as a geological term used to describe a volcanic effusion. *Rate* would translate as "taxa," meaning a ratio between two measures with different units, so that adding "taxa" allows a literal translation of *instantaneous effusive rate* as "taxa de efusão instantânea." For time-averaged measures, it is not possible to use a literal translation because *averaged* is a verb that does not exist in Portuguese, and *average* and *mean* both translate as "média." The term *discharge* can translate as "descarga," but such a translation can be confusing because it is not a well-constrained term and has several meanings. "Débito" is thus a more appropriate term because it corresponds to the "volume flow rate of a liquid." Within these constrains, and aiming to convey consistency when communicating the concepts, the terms *time-averaged discharge rate*, *eruption rate*, and *mean output rate* can translate as "débito" with different time-dependent provisos added, so that "média temporal do débito" would emphasize the *time-averaged* ("media temporal") nature of the *discharge* ("débito"); "débito acumulado" stresses that the measurement refers to the *discharge* ("débito") derived from a cumulative volume ("acumulado"); and "débito médio da erupção" indicates that we are referring to an *average discharge* ("débito médio") for the *entire eruption* ("da erupção").

(9) In the German language, there are no well-established translations for the four terms to be translated. There are two ways to translate these terms into German, either by (i) a direct word-for-word translation, or (ii) use of an equivalent German expression that best captures the meaning of each term. The terms given in table are those that best capture the meaning.

The two general terms *eruption* and *effusion* both have a straight translations into German. The term *eruption* can be traced back to the Latin word "erumpo," which means "to burst out". *Eruptio*n in German is thus an umbrella term for any type of volcanic eruptive activity (Murawski and Meyer 2004). *Effusion* likewise translates to "effusion" which, as defined by Murawski and Meyer (2004), is a description of the outflow of volcanic lava and goes back to the latin word "effundo" which means "pouring out". Following the German definition of "effusion" by Murawski and Meyer (2004), *effusion* implies *flow*, which in German is "Fluss." The German word "Fluss," when used in a physics context, implies that this is a quantity per time, so technically the second term *rate*, is not a necessary addition. However, according to the German encyclopedia *Brockhaus*, effusion is the "outpourring of lava" and does not include the term *flux*. Therefore, the best translation of *effusion rate* into German would be "Effusionsrate." We note that the German word "rate" is, however, somewhat technical, and the lay man would generally associate this with the rates one has to pay on a loan or mortgage. Instantaneous could either be translated to "augenblicklich" or "momentan," where the second adjective better captures the meaning of a specific moment. Thus, *instantaneous effusion rate* is best translated as "momentane Effusionsrate." Note, though, that if one refers to a point in time in the past, the exact date needs to be mentioned, otherwise it is assumed that this is the current rate (i.e., as of today).

The term *time-averaged discharge rate* includes the word *discharge* that if translated directly into the German language, would be "Ausfluss," so that "zeitlich gemittelte Ausflussrate" would be the direct translation. Here, "zeitlich gemittelt" means "averaged over time," and the time period over which the averaging has been made would need to be added to be precise. However, "Ausfluss" has a general geological context and is not a volcanological term. Thus, to cover the fact that the definition refers to the volume of lava erupted over a given period of time, a better translation would be "zeitlich gemittelte Effusionsrate", as given in the table.

As already stated, the literal translation of *eruption* would be "eruption." This term includes any type of eruption from effusive to explosive, i.e., emission of lava flows, but also ash, lapilli, and bombs. The direct translation would therefore be "Eruptionsrate." According to the definition given in Harris et al. (2007), however, eruption rate refers specifically to an amount of lava, i.e., effusively erupted material and not explosively erupted material. In this case, a better translation would be "Effusionsrate" so as to specify the effusive nature of the flux. To include the fact that we are considering the total volume of lava erupted since the onset of eruption divided by the time since the eruption began, the proper German expression would be "mittlere Effusionsrate seit Eruptionsbeginn."

Likewise, there is no direct translation of *mean output rate* into German. *Output* in German typically means "amount of production or production power" which, in the German language, is "Produktionsmenge" or "Produktionsleistung." These are rather technical terms which refer to industrial production and are therefore not really appropriate. The definition given by Harris et al. (2007) refers to the total erupted volume (here no distinction between effusive or explosive is made) so the German word "Eruption" can be used. As it is a rate we are referring to, we can use "Eruptionsrate," and because it is averaged over the entire eruption duration, we arrive at "Eruptionsrate gemittelt über die gesamte Eruptionsdauer." However, if examines Barberi et al. (1993) "lava output" is also used, which would yield "Effusionsrate gemittelt über die gesamte Eruptionsdauer." We include the former term in the table.

make classification schemes and technical vocabulary globally accessible, appropriate translation and definition of terminology is essential. In providing this, the translation must be appropriate as well as grammatically and lexicologically correct while avoiding false friends and words that have misleading connotations. The term also needs to be used consistently across all institutes and carry the same connotation or definition whether used by person A or person B in country Y or country X. We found that achieving such a translation system is no easy task, with major problems being dialects, false friends, and inconsistency of word definition and meaning, even within a single language.

Dialects

Indonesia has 78 historically active volcanoes and 76 volcano observatories (http://volcano.si.edu/region.cfm?rn=6) and 719 different dialects. In such a case, completing a translation for all dialects is an impossible task so that forum-based discussion is required to reach a term that works in and is recognized across all dialects. Indonesia uses Bahasa Indonesian as the cross-dialect language. Because 79.5% of the population aged 5 years or over perform everyday household communication using local dialects (BPS 2010), the use of Bahasa Indonesian is a necessity if a common understanding is to be achieved. In Bahasa Indonesian, many words for volcanological terms are adopted from foreign languages, especially from the English language, such as "efusif" for *effusive*. However, a few words have been merged from local (especially Javanese) dialects, so that—for example—Bahasa Indonesian uses "wedhus gembel" (literally meaning *hairy goat*) for *pyroclastic flow*. On the other hand, Bahasa Indonesian has given the world the word "lahar" which is now the international term for volcaniclastic hyperconcentrated flows and debris flows.

Intralinguistic problems

In putting this forum together, there was some discussion regarding the need for different sections for Castilian Spanish and Mexican Spanish and consideration of differences in word usage and meaning between Colombian, Peruvian or Chilean Spanish, or between Guatemala, Costa Rica, and Ecuador. We note that in some countries, one word is more popular than in others, but this does not mean that the other words are incorrect. There was debate, for example, of the use of "descarga" for *discharge* which would not be used in Castilian Spanish, because it means to unload or download and is used for electrical discharge but not frequently for liquids. However, it is used for fluids in Mexico (see Table 1, footnote 2). Castilian Spanish would instead use "caudal," as used for river flow. In these cases, it could be best to introduce the English term or a close relative to it. This, for *effusion* would be "efusión," where some Spanish dictionaries do define "efusión" as the pouring out of a liquid, as well as "the enhanced expression of hearty, happy feelings". Thus, although the term "efusivo" does not yet exist in the royal academy of the Spanish language dictionary as an equivalent for effusive, it does exist in the world reference dictionary, and the term "volcan efusivo" has been used for more than a century in both Latin-America and Spain. We argue that words such as *effusion* are now so widely used in the literature that introducing new, alternative terms in another language may only make the concept confusing. In the case of some languages, introducing a new and foreign term simply requires addition of the correct article (masculine or feminine) in front of the foreign noun, which in Italian requires adding the masculine article (i.e., "il").

Inconsistency of word definition

The problem of the false friend and impossibility of direct translation is an issue that comes up multiple times in the notes of Table 1. This problem can be accentuated by inconsistency of word definition across popular dictionaries in the same language and by the fact that the same word may also have several non-scientific meanings. If such a word is taken out of context, it may deliver an unintended message. In French, for example, the term *weathering* is translated to the term "altérer" (i.e., to alter) by Michel et al. (2004). In English, the term *alteration* has an altogether different meaning and connotation than *weathered*. Instead, the French dictionary of geology published by Dunod (Foucault and Raoult 2010) offers the term "météorisation" for the equivalent of *weathering*, defining it as "alteration of terrain under the action of meteorological agents." Unhelpfully, though, Foucault and Raoult (2010) add that "météorisation" is a term that is "little used," indicating a preference for the term "altérer" (which was updated to a preference for "altération météoritique" between the fifth and seventh editions of the dictionary). To complicate matters further, one general French language dictionary (Le Petit Robert) iterates the geological usage of "météorisation," but also reserves the term for "inflation of the abdomen due to gas accumulation in the digestive system." The problem of consistency in definition is confirmed by reference to the Hachette and Oxford French—English ▪ English–French dictionary which does not recognize "météorisation," but adds a third term to the mix by offering "s'éroder" (to erode) as the French equivalent for weathering "of rocks or landscape." This is partly correct because according to the geomorphology glossary of Delcaillau (2011), "météorisation mécanique" applies to surface erosion by meteorological factors, such as action of freeze-thaw cycles. There is also "météorisation chimique" which should be the equivalent of *chemical weathering* in English. However Derruau (1988), in another geomorphology glossary, defines this as biochemical process acting on rocks

and minerals "at depth, at high temperatures and by hydrothermal circulation," which sounds more like a definition of hydrothermal alteration than of chemical weathering. In such a case, a student or lay person new to the subject (and without access to specialist textbooks or to an expert) will obtain a different impression of term-meaning depending on which dictionary is used and will likely end up quite confused if multiple sources are consulted. Our discussion here raises two other points. First, a specialist would likely not use a standard language dictionary, such as Le Petit Robert, Larousse, Oxford English Dictionary, or Merriam Webster's to define scientific terms in their field, but a journalist or politician might. We thus need to be aware of definitions given in such popular sources and the perception of the process it may generate. Second, consistency is required within any single scientific culture.

Let us now add the complication that for the Spanish language, there will be preferred synonyms and verb usages in Spain and the many Spanish-speaking countries across the Latin-American region so that what might seem appropriate for a Mexican may not be appropriate for a Peruvian or a Colombian or an Argentinian. For example, in Mexican-Spanish, two words exist for *weathering*, these being "intemperismo" and "meteorización." The former though, does not exist in Castilian-Spanish. We may argue the same for the English language, where in English-English our aim is to *standardise* a global system, whereas in American-English we would seek to *standardize*. Our aim is not to standardize spelling systems (although a spelling system must be used consistently within a single document) but instead to allow for communication within and between languages in a manner that is clear, accessible, recognized, consistent, avoids confusion, and which, most importantly, delivers the intended message. In this regard, we follow the lead of Michel et al. (2004) whose dictionary provides both American-English and English-English translations for French terms taking into account differences in the spelling system and nuances in word usage between the USA and UK. For example, Michel et al. (2004) translates the French term "éclat gras" into "greasy lustre, soapy luster (US)." Such a caveat appears particularly important for English and Spanish where a language has spread across continents and doing so has evolved differently from country-to-country.

Acronyms

In attempting to produce multi-lingual acronyms, our test was negative. We simply ended up with too many confusing acronyms for the same term. We thus stress that use of *acronyms* are *not helpful*, as these vary from language-to-language and mean that native English and non-Native English speakers will become lost when presented with texts and talks that include usage of acronyms. We thus advocate an avoidance of acronyms in communications. The Chicago Manual of Style recommends that "the use of less familiar abbreviations should be limited to those terms that occur frequently enough to warrant abbreviation – roughly five times or more within an article or chapter – and the terms must be spelled out on their first occurrence" (University of Chicago Press 2010). Take for example, MOR—as used here for mean output rate of lava during an eruption. MOR is also commonly used to abbreviate *mid-ocean ridge*. If we type *mid-ocean ridge MOR* into Google Scholar, we find 36,000 returns, although it is not until the year 1983 that we see a return for the abbreviated form of mid-ocean ridge, with Francheteau and Ballard (1983) being among the first to write "mid-ocean ridge (MOR)." This, we note, is not an abbreviation related to mid-ocean ridge basalt (MORB), but is just a shortcut so that a phrase such as "segments of the mid-ocean ridge" can become "segments of the MOR." By the year 1982, 18,500 (50%) of the articles returned by Google Scholar dealing with mid-ocean ridge issues had been published, without recourse to a need for abbreviation. On the other hand, some acronyms (such as MORB) are so well known and accepted as international references that they may not need to be translated, a point which will also applies to many geochemical and physical standards.

Communication beyond science

On a local level, we point to the need for flexibility. If communicating with local stakeholders, we may need to adopt a different language than the one we would use within a scientific group. Crucially, the layman equivalent of a scientific term may have a completely different meaning when translated. For example, "volcanic spreading" can be translated into Spanish as "esparcimiento volcánico." However, the word "esparcimiento" has three meanings in Spanish: spreading, being socially at ease, and fun; so, when the word is used beyond the scientific community, the implication might be, for example, that the volcanoes are having fun. As a result "expansión" or "propagación" could be good alternatives. Likewise in Italian, "tasso" can mean *flux* or *badger* (see Table 1, Footnote 3). In this case, we need to recognize and adopt the terms that make more sense locally (even if that means having several terms for the same measurement) or to clarify the exact sense in which we are applying the word. Likewise, we need to recognize that groups with, for example, industrial or management cultures, rather than an academic culture will have different linguistic preferences, styles, and terminology systems. Ultimately, the usage of words is a personal choice, and there will always be situations where a single word will have several different translations, and different individuals may not always feel that a term used by another person is necessarily the best option. However, what is argued here is a need for consistency and consensus in translation of established nomenclature, with recognition of regional caveats

which are identified through open forum discussion, but that does not cause the community to arrive at several different terms for the same phenomena.

Definition with imagery

When communicating between languages and even between different disciplines in the same language, imagery is well-known to be more effective of memory retention of message than words (e.g., Standing et al. 1970; Neisser and Kerr 1973; Paivio and Caspo 1973; Standing 1973). Numerous studies thus argue that learning is maximized if communication is delivered in a mixture of narrative and imagery (e.g., Mayer and Anderson 1992; Mayer and Simms 1994; David 1998). The graphical representation of the definition system on which we focus here, as sketched up during our discussions to resolve the differences in meaning of each term among members of this forum, is given in Fig. 1. Following Stewig (1992), Fang (1996), Sipe (1998), and Carney and Levin (2002), we very much support the use of illustrated dictionaries as a facilitator of effective term meaning and message delivery for cross-cultural and cross-linguistic communication.

Translation forum

The scope and fluidity of our debate supports the need for an international committee charged with establishing and continually revising translations, while maintaining notes on the issues associated with each translation (e.g., Table 1). This committee, ideally a commission of IAVCEI, would thus be charged with proposing a formal nomenclature translation scheme, with a wider consensus, through an open forum. This might occur in two stages. First, the committee would set up an open and interactive online discussion forum (using an open source bulletin board-type software) where anyone could become a member of the forum and contribute. There could be sub-forums for each language. Eventually, we would envisage the committee acting as an editorial board for a multi-lingual translation dictionary for all core, volcanological languages. Given the scope of such a dictionary (which if following the lead here would translate into nine different languages and three different alphabets) a thematic grouping of terms may be better than the traditional, alphabetic dictionary approach. That is, one section each for magma terms, effusive volcanism, volcanic clouds and plumes, pyroclastic density currents, hydrothermal systems, and so on. These categories could be identified and laid out by the steering committee as "sticky posts" on the forum with a list of initial keywords in need of translation in each category; a list which—of course—would not be exclusive. Continual updates would be required to take into account the continual evolution of our languages.

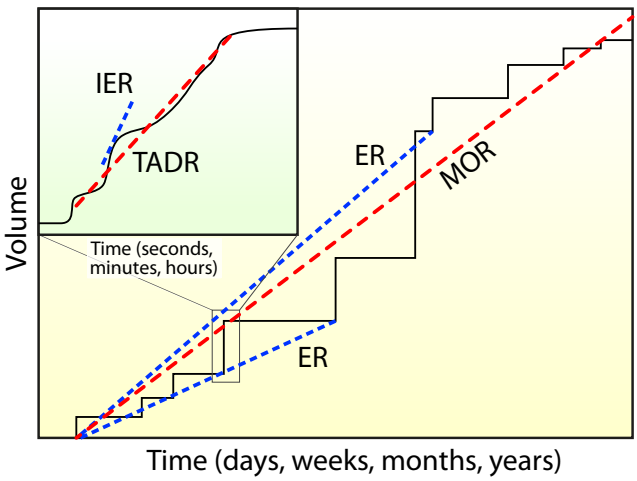

Fig. 1 Graphical representation of the meaning of effusion rate (IER), time-averaged discharge rate (TADR), eruption rate (ER), and mean output rate (MOR)

Conclusion

Our attempts at a global translation scheme that retains the meaning of a volcanological term, while respecting language-to-language grammar, alphabet, and lexicological differences led us to four main conclusions. That is, an effective translation system needs to obey four rules:

1. It must obey alphabet and accent formats;
2. It must be lexigraphically correct;
3. It must be grammatically correct;
4. While maintaining and conveying the intended meaning of the term.

The term should also be unique and non-overlapping. That is, there is only one word for each object or process so that there is no confusion as to which word needs to be used. The key is, we need to agree on translation schemes that are consistent within a language and coherent across languages, and which delivers the correct message when communication is between science and other stakeholder groups or cultures. This need, in volcanology, is pressing because modern terms often do not appear in even the best dictionaries of Earth Sciences and Geology. All terms considered here, for example, do not appear in the English–French ▪ French–English Earth Sciences dictionary of Michel et al. (2004), nor in the French dictionary of Geology (Dictionnaire de Géologie) of Foucault and Raoult (2010). The same is true for many other modern terms used in effusive volcanology such as the lava unit and flow-field classification terms of Walker (1972), the inflation terminology of Walker (1991), or the widely used dome classification scheme of Blake (1990). We therefore point to the urgent need for a forum that focuses on inter-language terminology transfer. Such a scientific translation

model has long been in place in the remote sensing community, if only for the French language. For this, in 1997, the Conseil International de la Langue Française (Paris, France) published the exhaustive tome entitled Remote Sensing Terminology (Terminologie de Télédétection). This definition and translation forum was charged with setting up, maintaining, editing, and updating a translation dictionary (CILF 1997).

The findings of our current inter-lingual discussion are that there is now a need for an international forum charged with laying out appropriate, consistent, non-overlapping, translations, abbreviations, and acronyms in volcanology. This international community service would be based on identification and continual review, of terms in need of multi-lingual conversion. A good starting point would be to apply the blueprint of Table 1 to the glossaries of the Encyclopedia of Volcanoes (Sigurdsson et al. 2015). Based on our many communication and translation experiences as teachers and researchers in non-English speaking countries, we argue that this need is a pressing one in today's internationalized world.

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