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1. Introduction

Transdisciplinary approach of science appeared in recent years, partially as a result of the urgent need to deal with global and planetary changes [1–12]. Transdisciplinary science is to answer and solve environmental science questions and problems became the foundation of sustainable development, nature conservation and various environmental science education including geoeducation [13–17]. Transdisciplinary approach within volcanology was always a key element of volcano science as volcanology addresses key questions over volcanic hazards, risk and resilience naturally moving along the interface of social science, humanities, natural science and non-academic (e.g. indigenous) knowledge [18–25]. Especially in recent years more and more researches were conducted on subjects to help to understand the interface between western science and traditional knowledge [26–30]. Such works explored various aspects of volcanism that affected the human societies greatly both as processes that produce natural resources for development and in other hand continuous fear that need to be dealt with to prevent societies from their destructive powers [28, 31–34]. The transdisciplinary aspects of volcanology is reflected well in the new volcano model and volcano geology approach to understand volcanic systems and placing them in a geosystem perspective [35] (Figure 1). In many volcano research aimed in recent years to develop some sort of volcano model that explain the volcanic processes, their resulting eruptive products, and the way such models can help to develop a better strategy for resilience against volcanic hazard within a general natural hazard framework [40–43].

2. From volcano geology to volcano model development

The various volcano models distinguish between type of volcanoes commonly categorized monogenetic versus polygenetic volcanoes (and volcanism) as a reflection of the total eruptive volume, the total duration of volcanic activity, the strength of the link to the magma generation source and the stability and longevity of a volcanic conduit [44, 45]. In these models obviously the end-member types of volcanoes define short, small, simple (versus long-lasting, large and complex. Recent decade of research in addition, provided ample evidences that the scale of observation (hence the detail of information could be mined from volcanic systems) is important, and provides evidences to support that in real world end member type of monogenetic volcanoes are rare, and most of them shows some sort of complexity in a near continuous spectrum [20, 46–52]. This is more apparent when the magma that form those volcanic geoforms are more evolved [53, 54]. In recent years attention
also turned toward effusive style of volcanism that is not obviously can fit into any of these categories. The current eruption of Iceland’s Reykjanes Peninsula that started on the 19th March 2021 8.45 PM (Local Time) provided and exceptional occasion to observe how a volcano start its life (Figure 2A and B). Commonly, the first moments of a volcano growth is missed by direct observation and later on the initial eruptive products become covered by subsequent eruptive products, missing key elements of the early, very critical phase of the eruption [55]. The new eruption in Iceland, that gradually building the new volcano Geldingadalir operating along an approximately 800-meter long fissure and at least 6 distinct vent zones (Figure 2A and B). The opportunity to observe the vent localization process commonly based on a combination of direct observation and study older volcanic successions [56, 57] is valuable to understand fissure-fed eruptions. Such geological observations and records can provide a dynamic view on fissure-fed eruptions in basaltic systems and help to interpret the resulting eruptive products (Figure 2C and D). In this respect the interlink between observation-based volcanology can be linked to various geoeducation works that provide good, evidence-based information to understand the volcanic geoheritage [58]. In case of the growth of the Geldingadalir volcano, it provides insight on the formation of steep spatter cones documented from the geological records elsewhere, for instance during the 1256 Al Madinah eruption in Saudi Arabia [59].

Numerous research work has been completed with a prospect to provide volcanic hazard maps [60–65] as well as some sort of tools to communicate to communities volcanic hazards [66], co-design, co-product programs and products to help developing a more resilience community that can live with the volcanoes and their hazards [28, 67–78]. In recent years, there is also a strong movement visible
In the last decades a boom of research is visible where volcanic geoheritage used and utilized as a main opportunity to develop geodiversity programs accompanied with effective geocuration programs (commonly formed as a result of citizen science, and co-design) to build a more resilience society against volcanic hazard. Even new terms appeared such as social volcanology or paleo-social volcanology steamed from social geology to express the newly and rapidly evolving discipline formed recently. Most of this works based on a more precise and process-oriented understanding of volcanic systems such as monogenetic volcanoes. The dynamic progression on volcanic geoheritage, geodiversity and geotourism research made a new aspect of volcano science where interface between natural sciences, humanities and social sciences meet and put into practical sense making volcanology a more relevant science to human society and our natural environment.

3. Volcanic geoheritage

Moreover in the last decades a boom of research is visible where volcanic geoheritage used and utilized as a main opportunity to develop geodiversity programs accompanied with effective geocuration programs (commonly formed as a result of citizen science, and co-design) to build a more resilience society against volcanic hazard. Even new terms appeared such as social volcanology or paleo-social volcanology steamed from social geology to express the newly and rapidly evolving discipline formed recently. Most of this works based on a more precise and process-oriented understanding of volcanic systems such as monogenetic volcanoes. The dynamic progression on volcanic geoheritage, geodiversity and geotourism research made a new aspect of volcano science where interface between natural sciences, humanities and social sciences meet and put into practical sense making volcanology a more relevant science to human society and our natural environment.
[103, 106]. In addition, an increased recognition of traditional knowledge and cultural aspects of volcanoes explored and made mainstream research outputs [107–111].

4. New advances in volcanology as a transdisciplinary science

Looking into detail of the recent evolution of volcano science we analyzed the accessible, mainstream literature data stored in the Thomson Reuters, Web of Sciences Core Database. Volcanology has two premier publication avenue such as Bulletin of Volcanology (Springer) [BV] that is also the official journal of the International Association of Volcanology and Chemistry of the Earth’s Interior. In addition, Journal of Volcanology and Geothermal Research (Elsevier) (JVGR) also considered as a main medium for scientific communication within volcanology. We were curious to see what research trend can be deducted from the published researches in the last 2 years (2019 to 2021, 20 April 2021) within these two premier Journals. We used search operators to identify keywords (including Author keywords and Web of Science generated keyword set). We understand that these keywords commonly reflecting general “umbrella subjects” and not obviously the main subject of the specific published papers, but we still think they are representative and informative to identify trends. For this, we created word clouds by using the WordArt online tool [https://wordart.com/] to visualize main keywords (larger words in more central position reflects more common appearance of such keywords). For the Bulletin of Volcanology 184 paper was identified. From these 184 papers keywords were extracted, while common non-informative words deleted as well as too generic words such as volcanism, volcano, volcanic, eruption, magma, lava, pyroclastic and based. In addition, manually all the location keywords were deducted and inserted to a separate file to see the common locations research focused in the past 2 years. Following this method, the Flow, Ash, Dome Size, Current words stand out reflecting the research output intensity around tephra and various geophysical flow research (Figure 3A). The rest of the keywords show a fairly even distribution across the entire spectrum of subjects. Applying the similar techniques to the JVGR, on the basis of 557 papers published in the same period of time showed keywords as most common to be System, Flow, Evolution, Model, Isotope, Hydrothermal, Fluid (Figure 3B). To look at the common locations current volcanology research associated with published within BV showed Bogoslof, Kilauea,
Puna, Andes and Etna as top for BV (Figure 4A), while Andes, StHelens, Etna, and Iceland having the most common location keywords for JVGR (Figure 4B).

The following method was applied for a narrower time frame (last 12 months) but looking at the title, keywords and abstract of the published papers in the two major volcanology magazines (Figure 5). From the 101 published papers the Erupt, Volcan, Volcano, Lava, Magma words were the most commonly used while in the “second” abundance more process-related words such as Flow, Deposit, Data, Model, Explosion, System, Observe etc. appeared.

As volcanic geoheritage became an important aspect of volcano science recently we checked the main keywords associated with researches identified under volcanic geoheritage topic search term from the Web of Sciences Core Databases. A total of
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79 paper has been identified in the time period between 2010 and 2021, suggesting the very recent formulation of this term (Figure 6A). To see this results in a perspective we made a keyword search for Geoheritage that resulted a total of 530 published papers between 2011 and 2021 (only 10 years!!). By removing the most non-generic terms such as Heritage, Geotour, Geoheritage, Geoconservation, Geosite and Geopark, focusing on those keywords that were identified between 10 and 100 occasions we can see that Volcanic is a common keyword within geoheritage studies (Figure 6B). This suggests that volcano science gradually build a strong corner within geoheritage, geoconservation and geoeducation. For curiosity we made a survey to check the published papers by searching Volcanic AND Transdisciplinary that resulted 8 published papers between 2015 and 2021 indicating the recent identification of this technical terms.

In summary we can say that volcano science is a very colorful and fast evolving science. Its transdisciplinary nature is getting more and more recognized and applied for a very diverse array of research areas and practical approaches to community engagement. This book offers another snapshot to this process.

Conflict of interest

The author declares no conflict of interest.
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