

# Environmental Education through an Interdisciplinary Approach: The Effects of the Volcanic Eruption of the Puyehue-Cordón Caulle Volcanic Complex on the Landscape of Southern Chile

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After the 2011 eruption of the Puyehue-Cordón Caulle volcanic complex (PCC) in southern Chile, an exhibition was prepared to show to the general public the findings of academic expeditions in the area affected. This paper discusses the objectives and content of this expedition, as well as the interpretation tools used to prepare it. A volcanic system operates (generally unnoticed) at different times and scales, creating a landscape of great scenic beauty. However, it is also a system that changes dramatically and can become dangerous. The exhibition made these changes visible to the community by using photographs, videos and oral discussions to convey the effects of the eruption on the landscape. The objective was to educate people about the differences between temporal visual effects (which are not always harmful) and others that cannot be observed but can damage the environment and for which we must be prepared. The discussion provides insight into the extent to which interpretation tools and landscape narratives can contribute to a full understanding of the dynamics and changes of natural landscapes.

## Landscape display and environmental education

Nowadays, a wide range of organisations deals with similar environmental challenges: to learn about and explore the natural world, and to re-interpret it into displays that can catch the attention of the public. For this purpose, acquired knowledge about nature needs to be transformed into environmental messages that can be conveyed to the general public in a useful way (Davis, 1996; Uzzell, 1989).

In the context of zoos, traditional cages are being transformed into habitats that replicate the environment of the animal species on display (for example, Valencia Biopark, Spain). Similarly, museums and botanical gardens are creating story-driven displays to heighten awareness of and concern about environmental issues (Davis, 1996; Falk and Dierking, 2002). Newer displays engage people with ecological processes that govern the natural environment (Monem, 2007; Villagra, 2011). In the same vein, universities have a responsibility to share research outcomes about the natural world with the public. In particular, they should share information about the direct effects of natural disturbances, using activities and messages that the non-academic community can easily understand and access.

The recent changes in the way the natural world is displayed are a response to global strategies developed by the Convention on Biological Diversity in June

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## REFLECTION

1992 at the United Nations Conference on Environment and Development, Rio de Janeiro, Brazil (Secretariat of the Convention on Biological Diversity, 2002). These strategies have influenced the objectives of organisations around the world that care about our ecological diversity. The aim is to use innovative environmental interpretation tools to enhance people's understanding of and relationship with the dynamics and elements of nature. Thus the concept of interpretation is as an 'educational activity which aims to reveal meanings and relationships through the use of original objects ... rather than simply to communicate factual information' (Tilden, 1977, p 8). It can be more effective if people are engaged with the topic of exhibitions through their own personal characteristics and values. In addition, the message needs to be narrated through appropriate media (Chang, Bisgrave and Liao, 2008); indeed, improving people's interpretation of environmental phenomena and associated effects can be a highly effective way of diminishing environmental risk and improving their environmental behaviour. When they are aware of the dynamics and effects of natural disturbances in their surroundings, communities have a more accurate understanding of the risks and are better prepared to initiate the process of hazard adjustment (Lindell and Perry, 1993).

However, improving the environmental interpretation of the dynamics of nature – including the timeframe in which they occur and the scale of their effects – is not an easy task because landscape change is usually slow, visible only after a period longer than the human life cycle (Bell, 1999). In addition, the scale of change may be too small or too big for people to see. To counteract these difficulties, scholars have suggested that exhibitions can be shaped as a story of natural processes, by using representative parts of the environment that people can understand easily (Potteiger and Purinton, 1998; Spirn, 1998). Also potentially useful are heuristic devices such as visual conceptual maps or graphs (Corner, 1999; Soliva, 2007). These and similar techniques are used to teach people to 'read' the landscape from new perspectives.

In the process of creating new exhibitions, it is important to consider that people can misunderstand environmental messages when the 'medium' becomes the 'message' (Uzzell, 1989). For example, where technology is overused, it becomes overwhelming and also conveys the wrong meaning. In the case of the Eden Project in the United Kingdom (Eden Project, 2009), for example, visitors engage with the exhibit itself instead of focusing on the topic of the display. Other, less provoking exhibitions can go completely unnoticed (Davis, 1996), creating a different kind of problem for communication.

Based on the literature concerning the challenges to educate people on a natural process and its associated effects, we discuss the approach taken by a group of researchers of Universidad Austral de Chile to convey to the regional and local society a basic understanding of the eruption of the Puyehue-Cordón Caulle volcanic complex during June 2011. We used a multidisciplinary approach to examine the effect of the volcanic eruption on the visual landscape and on the water quality and aquatic fauna of nearby rivers. Based upon the existing literature discussed above, we offer an innovative approach for gaining a greater understanding and appreciation of natural landscapes of southern Chile.

## The Puyehue-Cordón Caulle Volcanic Complex

The PCC is one of 500 active volcanoes of Chile (Sernageomin, 2011). It includes a strato volcano, a fissure zone and remnants of earlier Pleistocene volcanoes, all located in the Andean Southern Volcanic Zone at 40.5°S latitude (Singer, Jicha, Harper, et al, 2008). Its activity has been recorded from the Pleistocene to the present, with the latest three eruptions occurring in 1932, 1960 and 2011.

The area around the PCC corresponds to the lake region of Chile, characterised by the lakes Ranco and Puyehue and by rivers such as Iculpe, Muchi, Caunahue, Calcurrupe, Nilahue, Los Venados, Quiman, Coique, Riñinahue and Gol Gol. Foothills and valleys extend between 70 and 2,230 metres above sea level and a network of roads through them enables access to several small human settlements. The local economy is based on small-scale agriculture, fish aquaculture and tourism. This socio-ecological system was disrupted during the latest eruption of 4 June 2011. During this event, the temperature of several rivers rose, lakes were covered by pumice stone and entire human settlements were exposed to the effect of ashes. Indeed, the ash column reached 10 km high and affected the entire southern hemisphere. Ashes from the volcano reached Argentina, Uruguay, Brazil, South Africa, Australia and New Zealand, hindering daily human life, agriculture and air traffic activity across this region.

Following the day of the eruption, the media showed only images of destroyed landscapes, losing the opportunity to educate the community about the dynamics and process of the natural landscape in which they live. Yet the media can have a great influence on people's perception of landscapes (Jensen and McPherson, 2008). Furthermore, incomplete information can contribute to misunderstandings in the community, influencing the manner in which people interact with the environment and the decisions they make that affect their life quality and security. These considerations were among those that motivated a group of academics to study and communicate about the effect of the eruption on the landscape used for tourism due to its visual attributes and on the freshwater habitats useful for fly fishing (Figure 1).

### Expeditions and exhibition

This section offers an overview of the main results of each study, without describing the study methods and outcomes in detail. This content reflects the level of information that was most useful for preparing the story about the effects of the eruption of the PCC on the landscape.

### *The touristic landscape*

Although the PCC can create a risky environment, it has also been instrumental in shaping the territory by generating a landscape of high scenic beauty and touristic resources. However, local tourism is being described as not diverse enough to keep developing in the long term (Rivas, 1998). The objective of this study was to record landscape change in the touristic landscape, in order to explore how the visual changes due to volcanic activity could affect tourism. This aim was based on a growing interest in Chile and the region to develop Special Interest Tourism aimed at educating communities about the characteristics of their landscape (Agenda Local 21, Subdere and Programa Eco-región, 2008).

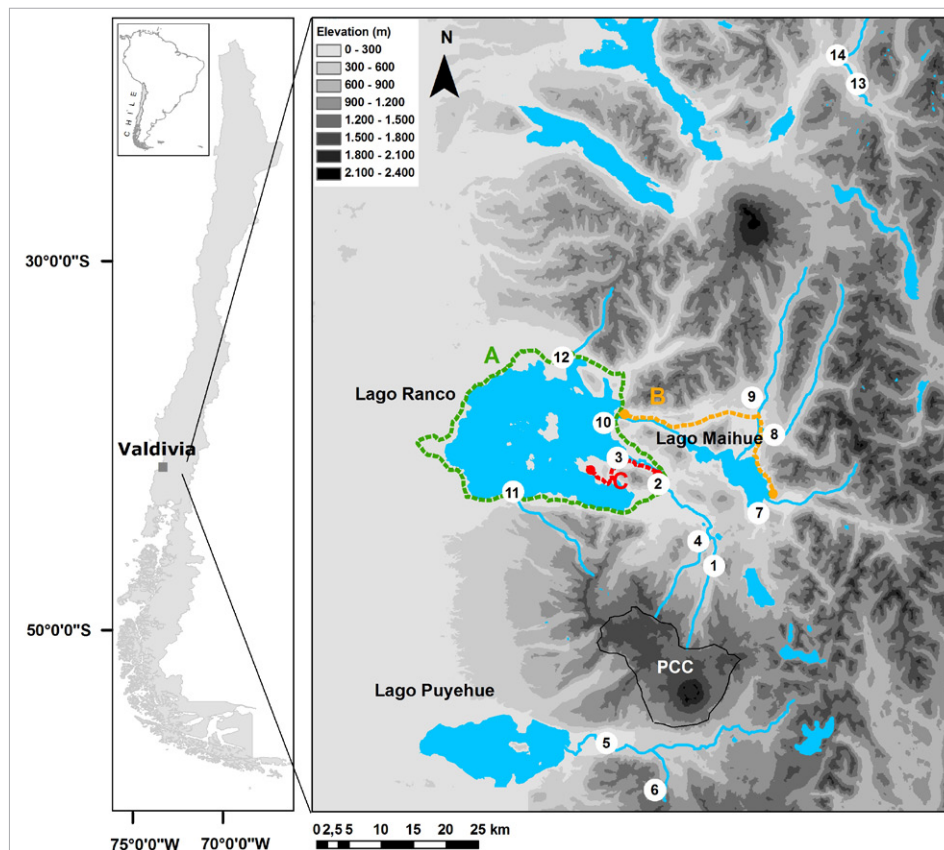


Figure 1: The Puyehue-Cordón Caulle volcanic complex in southern Chile. Circuit routes (A, B and C) indicate the areas covered to study visual changes in landscapes, while numbers refer to the river sites examined.

The study was focused around Lago Ranco where most of the tourist attractions are concentrated. The area is readily accessible and the lake setting is well suited to water sports such as rowing, boating and swimming. In addition, nearby rivers support top-quality fly fishing, which is highly prized. Visitors can enjoy nature while travelling by horse or on foot. All these attractions become even more desirable when they can be experienced while looking at a stunning landscape that features water bodies, a diverse topography with depth of view, ever-green trees, signal natural features and a variety of bright colours. According to landscape perception studies, people are drawn to all of these attributes in a landscape (Da Pos and Green-Armytage, 2007; Kaplan, Kaplan and Ryan, 1998). Such attributes also contribute to an area's restoration and recreation (Hartig, 2007).

During June, August and October 2011 and January 2012, 26 sites in the area were photographed by following the rephotographic technique to record visual landscape change over time (Figure 2). The sites were selected among the three most visited tourist routes of the area. The first route (A = 120 km) included a circuit around Lago Ranco; the second route (B = 50 km) ran from Llifén to Lago Maihue; and the third route (C = 35 km) started in the village of Riñinahue and extended to Bahía Illahuapi (35 km) (see Figure 1 above). This approach was taken to obtain a representative and comprehensive record of the landscapes that support tourism in the area and to avoid biases introduced by the researcher while selecting study sites (see Daniel and Boster, 1976).

Comparisons of the same landscapes photographed in the days and months following the eruption suggest that basic visual features were indeed affected by the eruption. In areas where volcanic material such as pumice stone and ashes was found, changes were evident in: i) colour, varying from bright to dull; ii) line,





Figure 2: Repeated photographs were taken from each site to the same vantage point after the eruption. Photographs were taken at eye level, in a horizontal position and with a 55 mm lens. The coordinates of each site visited were recorded with a Garmin GPS.

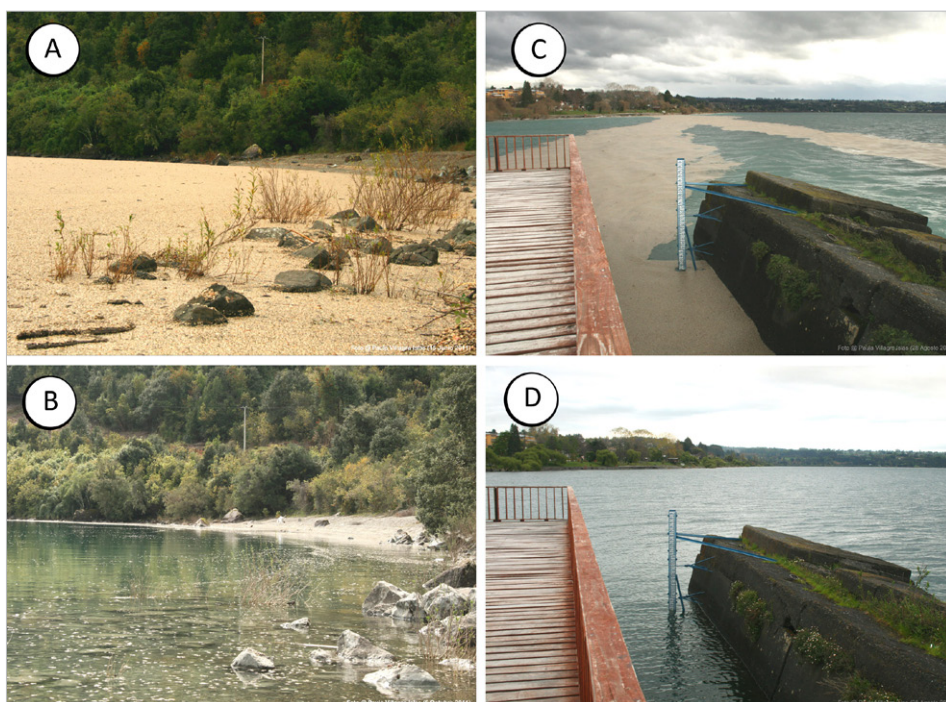
changing from blurred to sharp; and iii) arrangement of spatial attributes that define focused and dominant landscapes, in contrast to the usual panoramic landscape of the area (Figure 3). Changes were observed in water bodies such as lakes and rivers, as well as in landscape borders, such as beaches and promenades. As the images recorded with the rephotographic technique show, visual change is only temporary and the landscape recovers its visual attributes over time.

In summary, the findings from the expeditions to the area suggest several landscapes that are useful to convey the effects of the volcanic complex over time. These landscapes change visually but only temporarily, such that they do not damage the visual attributes of the landscape that make it so attractive to people. In the long term, therefore, such changes do not affect tourism that is focused on the scenic beauty of the area. The observed landscapes are included in the tourist routes of the area; however, they are not considered in tourism planning as a source of scientific and educational tourism.

### *The freshwater habitats*

Nearly three years before the volcanic eruption of PCC, researchers from the Institute of Environmental and Evolutionary Sciences had studied several rivers located around this volcanic area; that study included analyses of water quality,

Figure 3: Examples of changes in basic visual landscape features after the eruption, observed in Ensenada Beach (lower reach of Río Nilahue) (A and B) and Lago Ranco (C and D). Photographs A and C were taken days after the eruption in June 2011 and photos B and D four months later in October 2011. Photograph A is characterised by a sharp, horizontal line and high-colour contrast between the water body and the forest, while in photograph B the contrast of colours and the sharpness of lines are less marked. Similarly, photograph C depicts a landscape dominated by the body of pumice stone carried by the lake stream, in contrast to photo D which illustrates a more panoramic scene.



species richness and abundance of the freshwater macrobiota. Days after the eruption, therefore, they took advantage of that earlier work and moved to the field to repeat similar samplings at 14 river sites located to both the north and the south of the PCC (see Figure 1 above). Since then, samplings have been repeated during June 2011 and January, March, June and August 2012. The aim has been to analyse the effects of the eruption on water temperature and conductivity and on concentrations of total suspended particulate matter, silica and fluoride, as well as on the diversity and extent of aquatic insects and fish in the area. Because the eruption occurred during winter, flooding as well as fallout of volcanic material (pumice stone and ashes) contributed to the contents of particulate suspended matter on water during the first months following the eruption.

The results of the samplings show that rivers closer to the basement of the volcano had higher loads of pumice stone (Figure 4). In Nilahue River, for instance, samplings of the biota revealed a very low level of aquatic insects and a total absence of fish for several months after the eruption. In contrast, rivers somewhat further away from the basement of the volcano had lower loads of pumice stone (Figure 4). In addition, the diversity and extent of the biota were quite similar to those of rivers further away from the PCC or to the measurements gathered in the same rivers during the pre-eruption period (unpublished results).

In general, the water of rivers closer to the basement of the volcano had higher temperatures and conductivities (that is, more salts). The concentrations of total suspended particulate matter, silica and fluoride were also higher (Table 1). This difference most probably has arisen because the rivers Nilahue and Gol Gol received a higher load of material from the eruption, either through the air (ashes) or from the material flushed from the volcano.

During the first months after the eruption of PCC, water quality was the main concern of local communities and of officials from the regional and local governments. Thus much effort was devoted to explaining that the higher content



Figure 4: Load of pumice stones at the rivers Nilahue (A) and Gol Gol (B) two days after the eruption. The valleys of these rivers come down to the lakes Ranco and Puyehue from areas very close to PCC. In contrast, rivers Los Venados (C) and Anticura (D), which show lower loads of pumice stones, have valleys that are somewhat further away from the volcano.



<b>River</b>	<b>Temperature (°C)</b>	<b>Conductivity (µS/cm)</b>	<b>TSPM (g/L)</b>	<b>Silica (mg/L)</b>	<b>Fluoride (mg/L)</b>
Nilahue	12.6 (2.0)	293.5 (102.3)	1.26 (2.51)	17.6 (6.6)	0.33 (0.15)
Gol Gol	8.7 (3.1)	106.0 (17.4)	1.71 (1.50)	9.7 (2.5)	0.26 (0.05)
Los Venados	8.5 (2.7)	95.6 (28.7)	0.03 (0.02)	12.1 (2.0)	0.09 (0.03)
Anticura	6.6 (1.5)	60.7 (19.5)	0.03 (0.04)	7.1 (0.2)	0.04 (0.00)

*Table 1: Water quality of rivers located closer (Nilahue and Gol Gol) and further away (Los Venados and Anticura) from the basement of the volcano. The values are means (n = 5; except for fluoride where n = 3) with standard deviations in brackets. The samplings were carried out in June 2011 and January, March, June and August 2012.*

of pumice stones and ashes in rivers such as Río Nilahue was actually not proof of water pollution. In contrast, transparent waters without loads of that volcanic material could actually be quite polluted due to high concentrations of heavy metals, which are not visible to the naked eye. Coming into the spring, the ash plume extended west and northward arriving in several towns as far away as Temuco and Valdivia (about 200 km away from the volcano); thus the chemical composition of ashes triggered public awareness.

### *The story*

From the results of the above studies, it is clear that the pumice stone and ashes produce landscape changes, which may be positive or otherwise. On one hand, the accumulation of pumice stone and ashes generate changes that are visible in the main tourist routes. The volcanic action thus changes attractive aspects of the landscape in ways that may be less appreciated, but the finding does not imply that the environment is polluted. On the other hand, areas that are not visually affected by the eruption, such as transparent waters that do not accumulate pumice stones and ashes, can be highly polluted due to effects of other components not visible to the naked eye.

We found it interesting to present these results through a public exhibition. Here we could educate people about the differences between temporal visual effects (which are not always harmful) and other effects that cannot be observed but can damage the environment and for which we must be prepared. Our concern was to inform the community about the effects of a volcanic eruption on the natural landscape.

The most characteristic elements of the eruption – the pumice stones and ashes – were selected to create a story on the outcomes of both expeditions, which could be used to educate the community. In order to reveal evidence of a natural process triggered by volcanic activity, the story told of the effects of the eruption at different landscape scales and times, and of the extent of the effects on different landscape elements. Through the expeditions, it was possible to observe changes associated with environmental and visual landscape variables, such as the colour of terrestrial forms and water. Due to the different times and scales of the changes, people may well not notice them or, if the changes occur suddenly and appear to threaten their familiar environment, may view them negatively.

To help the community to interpret these issues, three different communication media were chosen: visual, auditory and verbal. The process of creating the story involved: i) selecting photos of visual, educational and scientific value that show landscape change in different scales and times (for example, see Figure 2 above); ii) creating audiovisual material; and iii) writing a narration of the effects of the volcanic complex in the territory (Figure 5).

**Visual aspect of ash at different scales and on different landscape features**



*Ash plume over the PCCVC, June 2011*

**Visual aspect of pumice stone on the lake shore at different times**



*10 June 2011*

**Selected captions of pictures presented at the exhibition to explain how non-evident fresh habitat features are analysed**



*Samplings to analyse changes in water quality due to effects of volcanic material run off*

*Figure 5: Examples of the photographic material selected to explain changes in different scales and times due to the pumice stones and fallout of ashes in the study area.*



*Ash deposited along Río Nilahue, 5 January 2012*



*5 October 2011*



*Samplings of aquatic insects to evaluate the effects of pumice stone and ashes on these benthic organisms, the food of fishes*



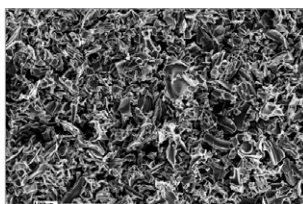
*Ash deposited on leaves of ferns, 5 January 2012*



*5 January 2012*



*Use of plastic graduated cones to evaluate loads of sedimentable material*



*Microscopic view of ashes deposited on the bottom of Río Nilahue*



*12 January 2012*



*Use of electric shock fishing machine to analyse fish communities*

*Selection of photographs.* On first approaching the exhibition, the community met with only visual content from which they could make their own interpretation. The selected photographs illustrated microscopic images of the ashes as well as panoramic views of its effects on the landscape. In addition, images taken from the same place but at different times were exhibited to emphasise the idea of change in the landscape and to add the concept of different timeframes to the display.

*Audiovisual material.* During the second stage of the exhibition, the objective was to add background material to complement the personal interpretation of the photographs. This new information would describe the relationship between the eruption of a volcano and the shaping of landscapes. After the community



had toured the exhibition, a video was played to emphasise the role of volcanoes in Chile and its evolution. Images, sound and text were used to explain how a volcanic eruption is generated, linking to evidence of the time and scale of such eruptions in the country. The video also familiarised the community with the recent fieldwork of the researchers.

*Narration.* Once the community had seen the photographs and video, and understood the effects of the eruption at different scales and times, researchers presented scientific information from the recent expeditions. After explaining the results of their own study, each researcher had a conversation with the audience.

The story of the PCC eruption of June 2011, shaped by these three tools of interpretation, was shared with a diverse community in a small village (Riñinahue) and with communities in the cities of Lago Ranco and Valdivia, all of which were affected by the eruption of the PCC. In addition, this story was exhibited in Santiago, the capital of Chile, which was not impacted by the eruption (Figure 6). In general, visitors found the exhibition a good source of information – feedback that highlights the relevance of this type of approach to environmental education. Inhabitants of the affected areas indicated that ‘it’s mostly a tangible proof of us, as locals, have seen and experienced’. Indeed, they describe the exhibition as a reminder of how remarkable the social environment was after the eruption: ‘it is interesting because (it was a time) I could share with the volcano, nature, life and family’. In this regard, local inhabitants suggest that the exhibition is a way ‘to inform and educate the community about the effect of natural phenomena present in our country’ (extracts from the Visitor Books, city of Lago Ranco, 2012).

### Landscape narratives, environmental education and the benefits of an interdisciplinary approach: final remarks

The manner in which the story and exhibition were produced relates to the proposal from Potteiger and Purinton (1998) on how to create landscape narratives. Such narratives comprise a set of events about nature, in which the aim is to inform people of natural processes and changes, and which could not be



Figure 6: Exhibitions and discussion with the communities in Riñinahue (A), Lago Ranco (B), Valdivia (C) and Santiago (D).

conveyed any other way. The story told to the Chilean public was framed by using representative parts of the environment that people can easily understand – the pumice stones and ashes. These iconic features can easily connect people with the volcanic environment.

Moreover, a narrative (as explained by Potteiger and Purinton, 1998) has a story (content) and a telling (expression). In this case, these elements were the stories about the effects of the volcanic activity in the touristic landscape and aquatic habitat, and the different tools of interpretation. These tools need to be selected according to the intended message with the aim of improving people's interpretation of phenomena of the environment and their associated effects (Chang, et al, 2008). For this reason, photographs and videos were thought to be useful tools to compare and reproduce landscape changes.

Another aspect of the narrative of this story was that it was developed by both landscape architects and scientists. Through this interdisciplinary approach, it was possible to show the landscape from different points of view, minimising the chance of introducing bias into interpretation. Such bias can create misunderstandings and, in turn, mislead the education system about the environment (Uzzell, 1989). The value of using an interdisciplinary approach is that it creates a story that gives more detailed and accurate information, helping the public to develop a better-informed understanding of landscapes that is less influenced by any one particular discipline.

The way in which the territory was decoded and recoded to create this landscape narrative has allowed the presentation of complex issues that are described primarily in academic journals and are rarely accessible to the general public. For this purpose, a highly useful approach has proved to be finding elements or parts of the landscape that have a dual purpose; these aspects must be central to research outcomes as well as easily recognised by the community. It is important to explore how to include other aspects of the landscape that change after a large natural disturbance, so that researchers can improve the public interpretation of it. For example, in the volcanic context it would be important to include the effects on flora and fauna, as well as on the cultural milieu.

The landscape is not just about what is visible but also about that which is hidden; the landscape is the result of different interacting stories, at different scales and times. The observation that 'what becomes visible and familiar, over time often becomes invisible' (Potteiger and Purinton, 1998, p 151) is relevant in environments that suddenly become dangerous, as they do in an active volcanic landscape. Landscape narratives, as described in this paper, can become a useful approach to improve environmental education about natural events, thereby increasing awareness about landscape change and its effects.

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