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(54) **METHOD AND DEVICES FOR DIVERTING LAVA FLOWS**

(57) Procedure and devices for diverting lava flows
by solidifying the edge of the flow with water.

With this procedure, the aim is not to stop the entire
flow but to create a barrier in an area so that the lava

takes another path.

Water can be applied by conventional means or us-
ing containers or devices that are part of the invention.

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Description

FIELD OF THE INVENTION

[0001] The present invention can be framed within volcanology and emergency response.

BACKGROUND OF THE INVENTION

[0002] In the information published after the recent eruption of the Cumbre Vieja volcano on the island of La Palma, it is always mentioned that there is no way to divert lava flows, so I do not believe there are effective precedents for the invention. They also mention that some methods have been attempted without success.

[0003] After filing the patent application with the OEPM, I have become aware of 4 possible precedents for the invention which I consider not to affect its patentability:

A1: RU 2057839 C1 (TALANOV BORIS P) 10.04.1996

A2: US 2004226301 A1 (DUBRUCQ DENYSE) 18.11.2004

A3: US 4451178 A (SPERRAZZA JOSEPH et al.) 29.05.1984

A4: Attempt to stop lava flows in 1973 on the island of Heimaey, Iceland.
(<https://icelandmag.is/article/when-residents-vest-manaeyjar-woke-discover-a-volcano-eruptina-outskirts-town>)

[0004] A1 discloses a method for protecting property from lava during a volcanic eruption. It considers the method of protecting property from lava by pouring water over the flow to be known and describes a more advantageous way to do so. It has significant differences from our invention.

[0005] The object of that invention is not to divert the flow, but to stop it. It does not propose that the lava take an alternative path. It makes a different use (application) of solidified lava barriers. To divert lava flows, barriers with a volume several orders of magnitude smaller than those used to stop them are sufficient.

[0006] The method of cooling lava using water is different, and in its case, it never proposes indirect application (without water-lava contact).

[0007] A2 describes devices that could be used to pour liquid nitrogen over a lava flow in order to stop it.

[0008] Like A1, the objective is to stop the flow, never to divert it. Additionally, it does not propose using water to cool the lava in any case.

[0009] A3 does disclose a method for diverting lava flows, but it does not use solidified lava barriers.

[0010] A4 describes the massive use of water to try to stop the flow. They mention the use of the same technique on a smaller scale in Hawaii and Etna. They also mention attempts to divert flows by building walls and

blocking streets. In this way, they make it clear that the objective of using water was to slow the advance of the flow, never to divert it. It also demonstrates inventive activity: for experts in the field, the use of solidified lava to divert lava flows is not obvious, even with the means to do so on the ground.

[0011] It would have been advantageous to stack steel drums filled with water, as described in the preferred embodiment of the invention, instead of building walls.

[0012] They used 6,000,000 m³ of water. With 1,000 times less water, 6,000 m³, most of it would be left over to divert the flow in strategic locations with our invention.

EXPLANATION OF THE INVENTION

[0013] When a volcano erupts and spews lava, the flows sweep away everything in their path. The invented procedure allows for the creation of barriers in strategic locations that channel the lava, forcing it to flow in another direction. These barriers do not aim to stop the lava flow; they merely impede its path so that it takes an easier route. They will be all the more effective the smaller the difference in energy between the blocked path and the alternative path. Especially useful in situations where current simulations do not allow knowing which path a flow will take, but there are two paths with a high probability. The more damaging path is blocked, increasing the probability of the other. This procedure can be likened to placing sandbags to prevent river overflow; the aim is not to stop the river, only to divert the water.

[0014] The procedure for creating these barriers involves cooling the edge of the flow with water, creating a crust of rock by crystallizing the lava. This initial crust may be knocked down by the push of the fluid lava, so water must continue to be poured, especially after each collapse. The edge of the flow will gain height, demanding more energy from the fluid lava to overcome it. If there is a path with less energy, the fluid lava will go there. Water must be continued to be poured until this happens.

[0015] Water evaporates upon contact with lava; the dangerous effects must be taken into account.

[0016] The barriers will preferably be created on the sides of the flow, but they can also be created at the front, or even on the top, to facilitate the formation of lava tubes.

[0017] If a lava tube is intended to be formed, it is advisable to cool only until the crust is stable and then stop supplying water to facilitate the flow of lava underneath. In other situations, side or frontal barriers, the more water supplied, the more lava is stopped, and the more effective the barrier will be.

[0018] Water can be applied directly to the lava or indirectly, heating the water by some container or device. With indirect application, the cooling of the lava will be somewhat slower, but equally intense. The amount of heat transferred from the lava to boil the water is the same in both cases, but if the water vapor is heated above 100°C, the lava will be cooled more.

[0019] Water can be applied by conventional means

or by containers or devices that are also part of this invention.

[0020] Two types of containers are devised, one preferably metallic, with direct and indirect water application. The other, of any material, with direct application mainly.

[0021] Both have one or more outlet ducts pointing towards the lava that only work when there is hot lava.

[0022] In the first case, preferably metallic, the outlet ducts pass over the water level, so it does not spill when cold. The origin of these outlet ducts can be below or above the water level. Depending on this, when the hot lava heats the container, it will expel water or water vapor against the lava, cooling it directly. If it expels water vapor, it is expected to heat above 100 °C, improving performance. The container material must withstand lava contact for a while, until the water is emptied, and must also conduct heat reasonably well, to heat the water and cool the lava. The simplest seems to be steel, but it can also be made of other materials, metallic, ceramic, or other types.

[0023] In the second case, of any material, indirect heating is not attempted. The outlet duct acts as a drain and is closed with a plug that will be the first to melt when the lava approaches. The violent boiling of the water upon contact with the lava must be foreseen, and all the water must be poured against the lava despite it.

[0024] Another devised device is a lava heat extractor. It has two parts, one to contact the lava, the hot focus, and another to conduct the heat to the cold focus. The materials must withstand the expected temperatures and must be good heat conductors. The design should seek low thermal resistance.

[0025] In the procedure we are describing, this heat extractor would cool the lava in the contact zone, allowing the barrier to be built to channel the lava with precision. The cold focus it would connect to would heat water. As long as there is liquid water and the lava remains above its temperature, heat transmission is assured.

[0026] This lava heat extractor device can also have other uses. It could be used to harness the thermal energy of lava, converting it for example into mechanical energy if the cold focus is the boiler of a steam turbine.

[0027] Another cooling material, liquid, or solid, can be used, and in the latter case, preferably granular. But water, usually with additives or impurities, tends to be the most suitable and cheapest material near a volcano. Any type of water, fresh, salty, clean, or dirty, can be used, as long as it does not pose a problem for the water application systems at the edge of the lava flow.

[0028] The amount of water needed to create barriers that divert the flow is significant but manageable. It will depend on each case, especially on the composition and temperature of the lava, but to get an idea, the volume of solidified rock is of the same order of magnitude as the volume of liquid water used.

[0029] This is not intuitive and is a consequence of the high latent heat of vaporization of water and the low specific heat of lava.

[0030] According to scientific literature, for lava, the

specific heat is around 0.3 kcal/(kg.°C), the latent heat of fusion between 65 and 100 kcal/kg, and the density between 2.2 and 3.1 kg/L, whereas, for liquid water, the specific heat is 1 kcal/(kg.°C), the latent heat of vaporization is 539 kcal/kg, and the density is 1 kg/L.

[0031] For example, to vaporize 1 liter of water at 40°C, about 600 kcal (2.5 MJ) are needed. About 60 kcal are needed to go from 40 to 100°C, and about 540 kcal are needed to go from liquid water to water vapor.

[0032] If we consider that this energy has been transferred by the same volume of lava, which could weigh 2.5 kg, it would need to transfer less than 250 kcal to crystallize and could have dropped more than 350°C by transferring the difference.

[0033] Note 1: Whenever performance is mentioned, it refers to the relationship between the amount of water used and the amount of solidified lava.

[0034] Note 2: When heat is transferred, the lava will increase its viscosity before reaching complete crystallization. This more viscous lava also acts as a barrier for the more fluid lava and helps it take another path.

PREFERRED EMBODIMENT OF THE INVENTION

[0035] There are countless ways to apply water to the edge of the flow. The most obvious is to use the same methods used to extinguish fires with water. All of them. To name a few, people or devices that direct jets of water at a certain distance using lances, or aerial transport means that drop water in the area of interest. The most typical, a fire truck.

[0036] They must be adequately protected against all harmful effects of the volcano and those produced when solidifying the lava with water, for example, against high temperatures, gases, ashes, or displacements of large masses.

[0037] The water supply can be from natural (lakes, rivers, seas, etc.) or artificial (pools, tanks, etc.) fixed or mobile water reservoirs. Pumps are usually needed to provide water pressure, and pipes and hoses to convey it. All of this is already used in firefighting. Irrigation systems can also be used.

[0038] Likewise, any type of water conveyance system can be used, such as drinking water networks or sanitation networks.

[0039] There are other sectors with tools capable of spraying water, such as water cannons at ski resorts or those used by the police to disperse demonstrations.

[0040] Another way to cool the edge of the flow with water may be to pre-place containers of water at strategic points where, having probabilities that the flow will go there, there are also probabilities that the cooled lava barrier that forms will be effective in diverting the flow.

[0041] The containers can be made of materials that withstand the lava's temperature or not, even with parts that do and do not.

[0042] In the case of containers that resist the lava, heat transmission may not be direct water-lava, but they

will still cool the lava, albeit more slowly. In this case, performance can be slightly increased if the container is designed in such a way that it directs the gases caused by the water boiling against the lava. The water vapor will come out around 100 °C, and the lava is expected to be much hotter, so it will cool down, and the water will heat up.

[0043] An example of this type of container could be a large steel drum with a lid with a conduit pointing towards where the lava is expected to reach. The outlet or conduit could be on the side of the container to facilitate stacking of the drums.

[0044] If it is foreseeable that the container, or part of it, will melt or break when the lava arrives, it will be much more effective if it is designed in such a way that when it breaks, the water is poured onto the lava.

[0045] An example of this type of container would be a pool, fixed or collapsible, located above the ground where the barrier is intended to be formed and at a certain distance away from the lava. The drain connected to one or more hoses placed towards the barrier, anchored to the ground in the last stretch and closed with an easily meltable plug. When the hot lava arrives, the plug or hose will melt, and the water will start to flow, cooling the lava. The violent boiling of the water could move the hoses, so the last stretch is anchored. The pool in this example can be replaced by any type of tank.

[0046] The use of the heat extractor can help design the solidified lava barriers. Any type of structure can be assembled where needed before the lava arrives.

[0047] The simplest examples would be a plate, a bar, or a steel mesh as contact surfaces, connected with copper cables to a container with water. There are alloys with high melting points and thermal conductivity.

[0048] The lava in contact with the extractor will solidify, albeit more slowly than with direct water application.

[0049] Another way to apply water may be to wet the ground before the lava arrives. Performance will be much lower, but if this water would otherwise be wasted, it may be worthwhile.

[0050] Obviously, several methods can be used in the same place, for example, leaving water tanks in an area, having firefighters come when the lava arrives to provide more water.

Claims

1. Procedure for diverting lava flows using solidified lava barriers comprising the following steps:

- a) Estimation of the lava trajectory.
- b) Identification of suitable locations in the path of the lava to form a barrier. The criteria for choosing the sites will be:

- i) Effectiveness of the diversion, achieving less destruction than the original path.

- ii) Ease of diversion by estimating that a smaller volume of barrier is needed or that it is easier to create.

c) Forming the barrier or preparing the site for the barrier to form when the lava arrives. The barrier is **characterized by** being formed by the solidified lava of the flow itself. The solidification is achieved by exploiting the high latent heat of vaporization of water by converting it from a liquid to a gaseous phase, exchanging thermal energy with the lava. The exchange is achieved in three ways:

- i) When the lava heats a container that holds water.
- ii) When the lava comes into direct contact with the water.
- iii) Through both of the above methods either simultaneously or alternately.

2. Container capable of being used in the procedure of claim 1, **characterized by** retaining the water content while there is no presence of lava and directing water towards the lava when the lava heats the container without human intervention.

3. Container capable of being used in the procedure of claim 1, **characterized by** retaining the water content while there is no presence of lava and directing the gases generated by heating the water towards the lava when the lava heats the container without human intervention.

4. Device capable of being used in the procedure of claim 1, **characterized by** conducting heat from the area where the lava is to be cooled to the area where the water is to be heated.

5. Lava heat extractor device **characterized by** having a contact surface with the lava and conducting heat from that surface to a cold source.

Amended claims under Art. 19.1 PCT

1. Procedure for diverting lava flows, **characterized by**:

a) Using one or more containers **characterized by**

- i) They contain water
- ii) The container material has high thermal conductivity and its melting temperature is higher than that of the lava it will come into contact with
- iii) The container is not airtight, it has holes

- or ducts through which liquids and gases can exit when lava approaches. The goal is to keep the pressure from rising too much so that the boiling temperature of the water does not stray far from 100 °C
- b) Placing the containers containing water where it is estimated that the contour of the flow that is intended to be stopped will reach.
- c) Cooling the lava, causing it to solidify, upon contact with the container.
- d) Forming a barrier with the solidified lava that diverts the fluid lava
2. Procedure for diverting lava flows, **characterized by**:
- a) Using one or more containers **characterized by**
- i) They contain water
- ii) They have a drain pipe that remains closed when there is no lava present
- b) Placing the end of the drain pointing to the area where it is estimated that the contour of the flow that is intended to be stopped will reach. Placing the container itself in an area where lava is not expected to reach.
- c) Opening the drain when the lava reaches the area intended to be stopped.
- d) Cooling the lava, causing it to solidify, upon contact with the water poured out by the drain.
- e) Forming a barrier with the solidified lava that diverts the fluid lava
3. Procedure for diverting lava flows, **characterized by**:
- a) Using a heat conductor device **characterized by**:
- i) It has a hot end that withstands contact with lava
- ii) It has a cold end that withstands contact with water
- iii) It has a circuit of a certain length connected to both ends that conducts heat from one to the other.
- b) Placing the hot end where it is estimated that the contour of the flow that is intended to be stopped will reach and the cold end in contact with water, at a certain distance from the lava
- c) Cooling the lava, causing it to solidify, upon contact with the hot end.
- d) Forming a barrier with the solidified lava that diverts the fluid lava
4. Container to be used in the procedure of claim 1, **characterized by**:
- a) It is capable of containing water and retaining it when there is no lava present.
- b) The container material has high thermal conductivity and its melting temperature is higher than that of the lava with which it will come into contact.
- c) It has one or more ducts pointing towards the lava
- d) The origin of the duct is above the initial level of the water
- e) The goal is to improve performance so that when hot lava indirectly heats the water, and it vaporizes at around 100 °C, the gases are directed through the duct towards the lava, cooling it.
5. Container to be used in the procedure of claim 1, **characterized by**:
- a) It is capable of containing water and retaining it when there is no lava present.
- b) The container material has high thermal conductivity and its melting temperature is higher than that of the lava with which it will come into contact.
- c) It has one or more ducts pointing towards the lava.
- d) The origin of the duct is below the initial level of the water, so that the water flowing through the duct starts out in the liquid phase.
- e) Some section of the duct exceeds the initial level of the water, preventing water from flowing out at ambient temperature.
- f) The goal is that when hot lava indirectly heats the water, the pressure inside the container increases slightly, pushing liquid water through the duct towards the lava, cooling it.
6. Container to be used in the procedure of claim 3, **characterized by**:
- a) It is capable of containing water and retaining it when there is no lava present.
- b) It has one or more ducts pointing to where lava is expected to appear and where a barrier is intended to be formed. These ducts act as drains for the container.
- c) The end of each duct has a fusible plug that prevents water from flowing out at ambient temperature.
- d) When the proximity of the lava heats the plug, it will melt or break, allowing water to flow out.
- e) The goal is for the water flowing through the duct to cool the lava upon contact.

7. Lava heat extractor device to be used in the procedure of claim 3, **characterized by:**

- a) It has a surface in contact with the lava made of a material with high thermal conductivity and with a melting temperature higher than that of the lava it will come into contact with 5
- b) It has a surface in contact with the water made of a material with high thermal conductivity.
- c) The two previous surfaces are connected by a low thermal resistance heat conducting circuit, for example, copper cables of sufficient cross-section. 10
- d) The previous circuit may have several parts made of different materials. 15
- e) The goal is to be able to separate the water from the lava at a certain distance

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/ES2022/070732

5	A. CLASSIFICATION OF SUBJECT MATTER	
	A62C99/00 (2010.01)	
	According to International Patent Classification (IPC) or to both national classification and IPC	
10	B. FIELDS SEARCHED	
	Minimum documentation searched (classification system followed by classification symbols) A62C	
	Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched	
15	Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EPODOC, INVENES, WPI	
	C. DOCUMENTS CONSIDERED TO BE RELEVANT	
20	Category*	Citation of document, with indication, where appropriate, of the relevant passages
		Relevant to claim No.
	X	US 4451178 A (SPERRAZZA JOSEPH ET AL.) 29/05/1984, column 2, line 64 – column 4, line 68; figures 1 - 3
25	X	RU 2057839 C1 (TALANOV BORIS P) 10/04/1996, Description. Abstract from DataBase EPODOC (Retrieved from WPI AN 1997-019542)
	X	US 2004226301 A1 (DUBRUCQ DENYSE) 18/11/2004, Page 4, paragraph [0043] - paragraph [0044]; figure 13
30	A	JP 2005024366 A (HITACHI LTD) 27/01/2005, Figures 1 - 9. & Abstract from DataBase EPODOC (Retrieved from WPI AN 2005-107302)
35		
40	☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.	
45	* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance. "E" earlier document but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure use, exhibition, or other means. "P" document published prior to the international filing date but later than the priority date claimed	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family
50	Date of the actual completion of the international search 01/03/2023	Date of mailing of the international search report (01/03/2023)
55	Name and mailing address of the ISA/ OFICINA ESPAÑOLA DE PATENTES Y MARCAS Paseo de la Castellana, 75 - 28071 Madrid (España) Facsimile No.: 91 349 53 04	Authorized officer P. López Calvo Telephone No. 91 3495413

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/ES2022/070732

Information on patent family members

Patent document cited in the search report	Publication date	Patent family member(s)	Publication date
US4451178 A	29.05.1984	NONE	
RU2057839 C1	10.04.1996	NONE	
US2004226301 A1	18.11.2004	US2012002776 A1 US2010146993 A1 US2007214808 A1 US7631506 B2 US2007089431 A1	05.01.2012 17.06.2010 20.09.2007 15.12.2009 26.04.2007
JP2005024366 A	27.01.2005	NONE	

Form PCT/ISA/210 (patent family annex) (July 2022)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- RU 2057839 C1 [0003]
- RU 10041996 C1 [0003]
- US 2004226301 A1 [0003]
- US 18112004 A1 [0003]
- US 4451178 A [0003]