USE OF EXPLOSIVES AND TORCHES FOR LAVA FLOWS DIVERSION VOLCANIC ACTIVITY SIMULATION AND FIRE FIGHTING

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ABSTRACT

In 1983 on Mt Etna we had the opportunity to divert lava flows: exploding the lava levee. Since that time we have developed a new method which is now operational. In order to perfect our knowledge of volcanic activity and lava flow behavior we developed the know-how of making it possible to create a small experimental volcano. The technologies developed to explode lava flows can be applied in extinguishing wild well oil or gas fires.

THE HISTORICAL BACKGROUIND:

Different attempts have been made to prevent destruction due to lava flows.

Pouring water or building artificial barriers delayed the lava front advance, but none were entirely successful.(Jaggar 1936;1937;1945; 1949; Mason and Foster 1953; MacDonald 1958; Williams and Moore 1973; Bolt *et al.* 1975; Kilburn 1983; Colombrita 1984).

More efficient techniques have been applied to disrupt the feeder tube systems.

In Hawaii in 1935 and 1942 the United States Air Force and volcanologists decided to attempt the diversion of a lava flow by bombing lava tubes. The bombing was found to be effective in breaking the cover of a tunnel or side of a small crater, but it lacked precision, especially when visibility was poor. This method can be ineffective when there is no suitable area to where the lava could be diverted, as in Kapoho in 1960, where the only protection was to build earth barriers (Jaggar 1936; Lockwood and Torgerson 1980).

MODERN TECHNOLOGIES:

Complete success has been achieved two times in arresting a lava front : in 1983 and 1992 on Mt Etna. In both cases the lava was diverted at the lava source, the molten rock being driven into a new channel, cooling faster in the open air, and covering the already solidified lavas of the same eruption. Both diversions were obtained using explosives: 390 kg in boreholes removed 200m3 of rocks on May 14, 1983; more than 7000 kg placed on the surface of the soil removed 50 m3 on May 26, 1992 (Abersten 1984; Barberi and Villari 1984; Lockwood and Romano 1985; Barberi *et al* 1993).

In both cases the initial diversion was only 30 to 40% just after the blast. During the following hours big blocks of rocks completed the work, obstructing the lava tunnel down slope. In 1983, they fell in the channel naturally; in 1992 they had been prepared in advance using an excavator with an hydraulic jackhammer and a bulldozer.

WASTING TIME:

On Mt Etna in 1992 a long time was wasted flying concrete blocks by helicopter, experimenting with big explosions on the surface of the lava flow, sinking iron crosses and iron chains in the active lava flow, and building earth barriers across the lava flow. The advantage of using surface placed charges despite the enormous quantities needed, was to avoid drilling and the need to cool the explosives in the high temperature bore holes heated by conduction from the active lava (Barberi et al. 1993).

These spectacular interventions were completly inefficients for the following reasons:

- the cross section ot the lava tunnels was 3 to 4 times larger than the concrete block size.
- armored concrete blocks are not refractory , they broke when heated in the lava
- the asbestos insulation of the iron chain delayed but did not prevent the temperature increase of the metals.
- surface explosions already tested in 1983 are inefficient as they don't affect the bottom of the burried lava flows

The 7000 kg of explosives placed on the surface of the soil the 26 of May were necessary even if the rock diaphragm to explode was only 3m thick.

THE NEW METHODS

Taking advantage of the 1983 experiment we proposed a new project based on drilling methods to the Italian civil defense on December 4, 1991 and submited it to the Commission of the European Communities in January 1991.
In both cases it was rejected.

The advantage of drilling can by listed as follows:
1- minimum waste of explosive energy toward the atmosphere;
2- explosive charges can be placed as close as necessary to the active lava, and at any depth;
3- blasted rocks and blocks can be produced at the site, and obtained to any depth and in large quantities of more than 1000 m3 per day using the up-to-date techniques;
4- explosives confined in rows of holes easily produce big blocks of refractory lava, while in contrast, surface charges pulverize the rocks, and bloks have to be produced away from the site, transported, and sunk in the lava channel;
5- modern boring techniques make it possible to both drill and install the tubes;
6- bore holes could have a diameter up to 180mm making possible to load as much as 40kg of explosives per meter at any depth;
7- boring equipments and compressors can be transported by helicopter even if the weight of the heaviest equipment is more than 6000 kg
8- excavators, buldozzers, drilling machines and explosives have already been used or tested on lava flows or wild wells burning oil or gas.
9- the field camp for the personnal can be quickly put up on site and the work can go on even in case of bad weather during the operation. (In 1992 the intervention lasted for 47 days, 15 days being lost for bad weather as poor visibility prevented the helicopter from bringing the operators in the field).
The total time necessary to complete an intervention with our new method was assessed to be 14 days: 7 days to prepare and set the field equipments, 7 days of field work including drilling and exploding.

EXPLOSIVES AT HIGH TEMPERATURE:

When drilling in 1983 we measured up to 900°C in the bore holes. Cooling was necessary in order to prevent deterioration or uncontrolled detonation of the explosives. Different cooling methods have been designed
1) Water cooling jackets. Water stored in a big reservoir circulates in a double wall tube, keeping the temperature below 60°C in the hole (Rodio system) (Volpe and Tonoli 1984)
2) Air guns: this method was designed by the Swedish technician Rune Gustafsson and is based on the principle of the Flobert compressed air gun. It makes it possible to load explosives from a distance using a pneumatic system.(Abersten 1984)
These first two methods were used in 1983, about half of the 55 holes being equipped with each. before detonating.This method saves water cooling and the amount of compressed air needed is minimal.

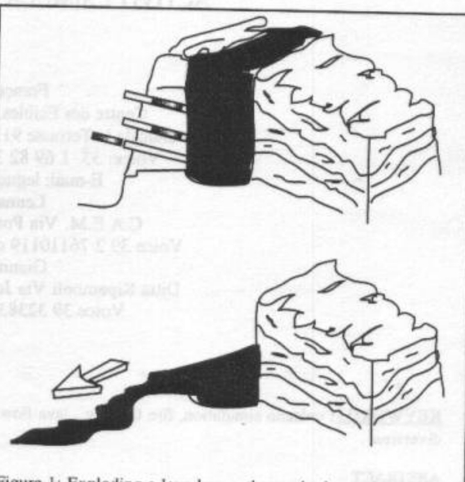

Figure 1: Exploding a lava levee: the method was designed and used in 1983: explosives are placed in horizontal bore holes. Water jacket or air guns prevent the deterioration by the heat transfer from the lava.

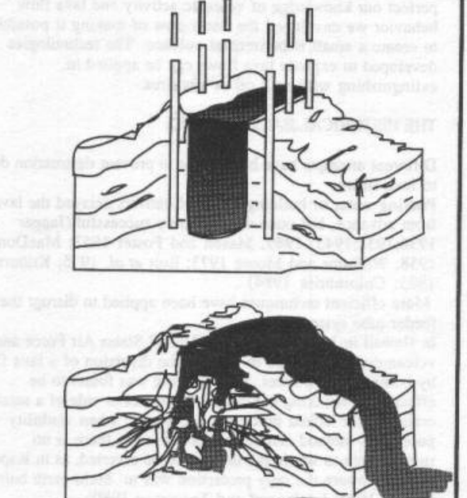

Figure 2: Gravity charging and exploding a lava tube: this method has not been tested in real size.

3) Gravity charging: This method was designed but had not yet been applied . Explosives are charged in vertical tubes overhanging the hot bore holes. Small pistons keep them suspended outside. A few seconds before blasting, compressed air removes the pistons, and charges fall in the hole just

THE ERUPTION SIMULATION

The project submitted to the Commission of the European Communities in January 1992 contained different testing methods:

- lava cutting using high pressure water
- lava melting using high temperature torches
- molten lava exploding by water injection

In order to perfect our knowledge of lava flow behavior a team of chemists, volcanologists, movie makers, and plastic art teacher supported by The "Gerland Company" supported a complete experience of artificial lava flow simulation in a basaltic quarry located in the Centre of France. Fusion was obtained by oxidation of iron tubes in pure oxygen. After different tests in the workshop and in open air the team succeded to create a small lava flow and a 1 m3 lava empoundment. Lava casts were also successfuly made.

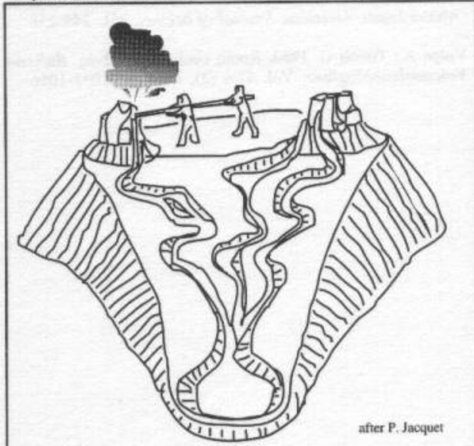

Figure 3: Experimental workshop as operated in Ardèche (France)

Analyzing the mother rock by the K, Ar dating method gave an age of 13 10^6 Years. The fused rock had a zero effective age as it was nearly completely de-gassed. During and after the test the fusion gases were collected and analyzed. They contained carbone dioxide, sulfur (as sublimate) and chlorine 150 to 300 mg/m^3. Many flames were observed on the lava surface. A small lava deviation was made by fusing the lava levee. The artificial volcanic activity is very similar to the same kind of phenomena observed on real volcanoes. This know-how already applied in cleaning fires or cuting reinforced concrete.makes it possible to design a "Small volcano laboratory" in order to simulate and study lava flows, magma de-gassing and gas differentiation in the soil and atmosphere. We could also test the effects of explosives on representative volumes of molten rock

FIRE FIGHTING WORK ON BURNING GAS OR OIL.

Tested in Kuwait, it is possible to approch a flamme 15 to 20 meters high, 1500 to 1600°C, as close as 3 to 4m (soil temperature 120°C at 20m). The approch was made with asbestos "COMASEC" equipments free of cooling air or water (Le Guern 1991).

Two methods have been developed and tested. They gain time and security during the capping and fire-fighting work:

Method 1: Cutting and cleaning of casing and/or well-head by means of remote control diamond-equipped devices.Total cutting of the casing takes about 2 hours.

Besides total cutting, we can also cut and take away the outside casing tubes, leaving the inner tube (in Kuwait 18cm in diameter) to be capped on, with specially built equipment.

Method 2: Utilization of explosives to weld a tube, possibly equipped with a closing valve, above the well-head. Welding by blasting has been done on surfaces flushing with petroleum, and has been tested to withstand at least 300 atm. The explosive charges can be placed in a special container (2 halves to put together outside the tube) which can be cooled by circulating water according to the know-how developed on lava levee disruption..

The tube being welded, the flow of petroleum or gas can be estinguished by closing the valve (Figure 4).

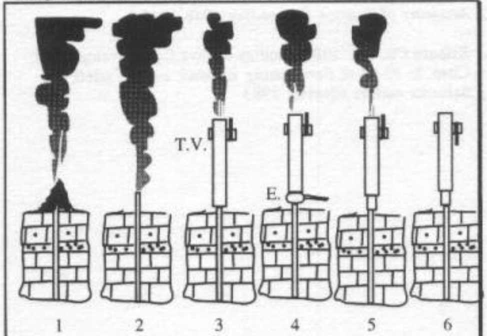

Figure 4. Fire fighting procedure:
1: Initial situation: the destroyed well head is surrounded by debris and solid silica condensation.
2: Cleaning and cutting with a remote control diamond equioed device.
3: tubing
4: blasting welding
5: the tube after blasting welding: pressure resistant to more than 300 atm.
6: stop fire and control
T.V.: Telecommanded Valve.
E.: Special container for explosives with water circulation system.

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