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Antarctic Volcanic Hazard

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Abstract : Along western Antarctica, from the Scotia Arc to Balleney Islands, the following zones with active Pleistocene-Recent volcanism have been recognized: 1. Sandwich Islands; 2. Bransfield Rift; 3. Larsen Rift; 4. Marie Byrd Land; 5. Hallet Land, and Victoria Land; and 6. Balleney Islands. In the eastern Antarctic region another active volcanic area related to the volcanic system of the Kerguelen Islands (Gauss volcano area) has been recognized. All these areas include a number of active volcanoes with recent historic eruptions. Therefore, they constitute regions with volcanic hazard, subjected to eruptive activity generating freatomagmatic explosions, avalanches (lahars) and tephra fall.

The siting of Scientific Bases, ports and landing fields, with a dense human and logistic concentration increasing over the last decades, has contributed to a rise in the number of points with "high risk" in case of eventual volcanic eruptions. Two are the main critical areas: a. The region of the Erebus volcano in the Ross Sea, on which flanks the installations of the following stations: McMurdo, Williams Field and Scott Base, among others; and b. The Bransfield Strait and Antarctic Peninsula region. At present, the concentration on King George Island and the South Shetland Islands consists of ten permanent Scientific Stations and the emplacement of the biggest logistic support facilities (landing fields, ports, meteorological equipment, telecommunications, etc.), never before seen, consitute one of the highest volcanic risk points of all the Antarctic Continent. Worthwhile remebering are the eruptions of 1967, 1969, and 1970 on Deception Island, and the disaster they caused at the Chilean and British Stations, should be projected to what could happen today, if an eventual eruption caught some of the aircrafts currently overflying the area with its tephra emission. In order to mitigate the effects of these natural catastrophes and to inform the stations in time, a seismic telemetric network has been implemented, to control the seismic-volcanic activity on the Bransfield Rift. This project should constitute an International Cooperation Program in the region, supported by all the countries that have a year round station operating in that area.

Key words : volcanic hazard, volcanic eruption, Antarctica

Introduction

The physical scenery of the White Continent, especially of West Antarctica, was framed by more than a hundred Pleistocene to recent volcanoes, many of which are active at present and exhibit historical records. Inserted in the complex tectonics of plates and microplates, with dynamic subduction processes, rifts and hot spots defining and controlling the magmatic eruptive characteristics which interacting with subglacial or shallow submarine masses generate determinant effects in the type of freatomagmatic, highly explosive eruptions. Being this the predominant volcanic activity in Antarctica.

Volcanic eruptions are natural processes in the Earth's evolution and therefore, they constitute a NATURAL HAZARD, capable of catastrophically modifying the physical scenario in a couple of minutes. At present, we can observe the permanent human settlement in Antarctica in the last decades, the installation of Scientific Bases and the emplacement of the

corresponding logistics, are all carried out in the surroundings of active volcanoes. The lack of knowledge about volcanic hazards and the high vulnerability presented by those human settlements, considering the possibility of an eventual volcanic eruption—which no doubt have a cyclic repetition, as demonstrated by geological history —have originated or transformed those regions subjected to Natural Hazards into zones of HIGH VOLCANIC RISK. In order to encourage the investigation oriented to the monitoring of volcanic activity, to decrease vulnerability and mitigate the effects of future eruptions, within the context of an International Co-operation Project, in agreement with the SCAR's philosophy and the Antarctic Treaty, a global vision of the VOLCANIC HAZARD IN ANTARCTICA is here given.

Volcanic Hazard Region

Figure 1 and Table 1 show that active volcanism is concentrated along Western Antarctica, from the Scotia Arc to Balleney Island. The following zones with active volcanism have been recognized:

a. South Sandwich Islands (Baker, 1990);
b. South Shetland Islands-Bransfield Rift (Gonzalez-Ferran, 1990; Smellie, 1990);
c. Larsen Rift (Gonzalez-Ferran, 1983; Smellie, 1990);
d. Marie Byrd Land (Gonzalez-Ferran and Gonzalez-Bonorino, 1972; Le Masurier, 1990);
e. Hallet and Victoria Land (MacIntosh and Kyle, 1990; Kyle, 1990; Kaminuma and Kyle, 1988);
f. Balleney Islands (Wright and Kyle, 1990).

In the Eastern Antarctic region, another Holocene volcanic area, related to the volcanic system of the Kerguelen Islands, Gaussberg volcano area, has been recognized (Tingey, 1990). All these areas include a total number of 26 active volcanoes, some of them with recent historical eruptions. Therefore, they constitute regions with volcanic hazard, subjected to new freatomagmatic volcanic eruptive activity (subglacial and shallow submarine); lahars and tephra fall any time in the near future.

Many of the eruptions which have occurred in Antarctica in historical times have never been directly observed by men, due to the nature of the Antarctic Continent, being the most isolated and uninhabited in the whole world. Only in the last decades has man been able not only to observe some eruptive processes but also to live its effects and to suffer the impact of important material losses.

Considering geological and historical data of eruptions, they are no doubt characterized by their freatomagmatic explosions with abundant generation of tephra which ascends to a remarkable height and spreads following the predominant direction of the wind (east-northeastward, i.e., clockwise over Antarctica). Thus, tephra fall may extend for many kilometers from the actual zone where a volcanic eruption occurs, creating a zone of high risk, especially for the areas overflown by airplains and other scientific air-operations, in regions sometimes far away from the point of the actual eruption. In the same way, similar phenomena of expansion and trend of propagation of volcanic material ejected during submarine eruptions due to submarine currents circulating around the Antarctic Continent have been observed.

Some Historical Eruptions

It is worthwhile recalling some of the eruptions which have occurred over the last decades in Antarctica, as a lesson to be learned and never to be forgotten. Antarctica still presents a seismo-volcanic activity due to its dynamic tectonics, as many other regions on the Earth. This is especially relevant today, when the exploitation of mineral resources in Antarc-

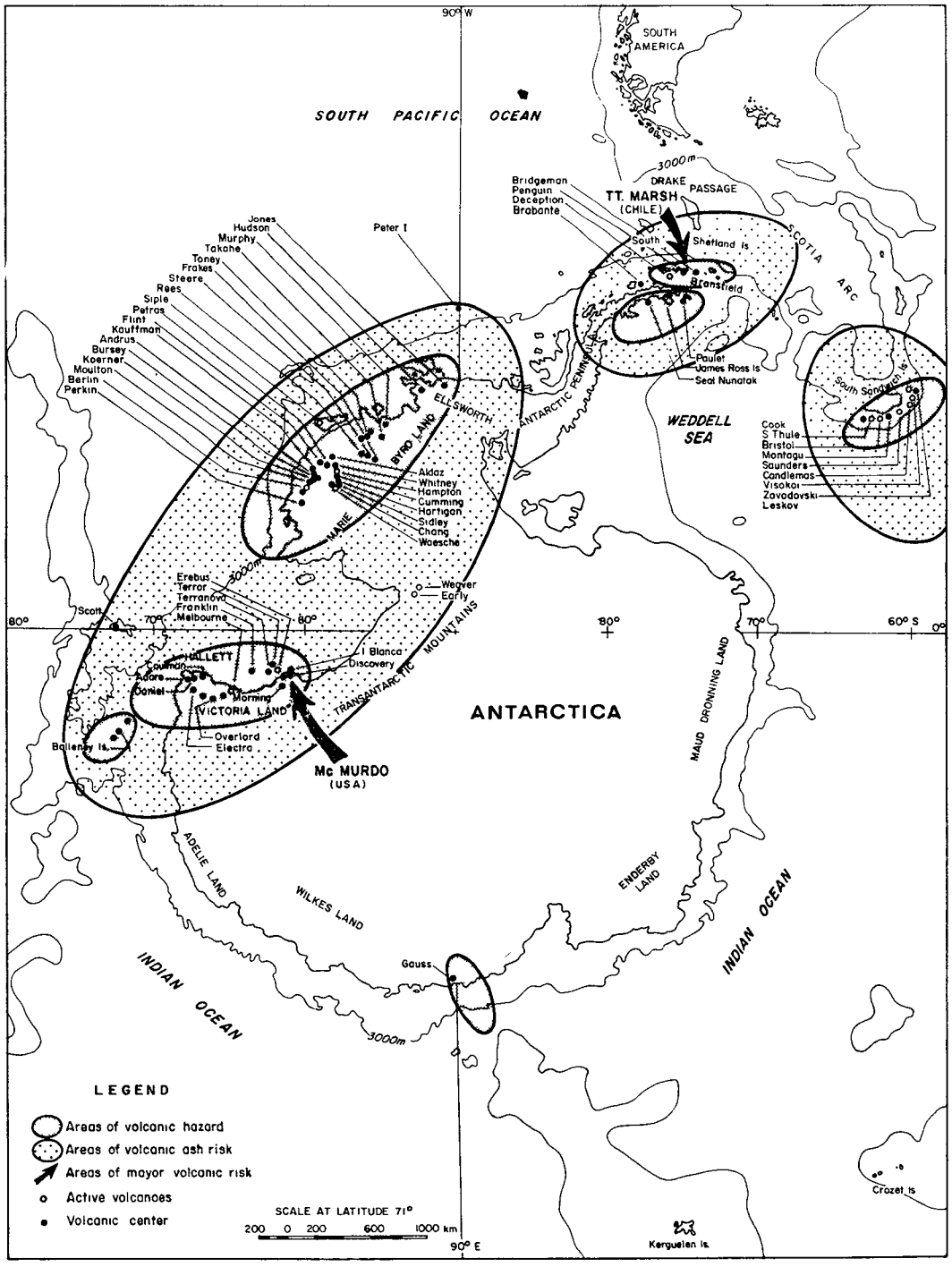

Fig. 1. Distribution of the Volcanic Hazard Region in the Antarctic continent.

Table 1 Antarctic Volcanoes with historical activity

Volcano	Funarolic activity	Historic eruption	References
SOUTH SANDWICH ISLANDS			
1—Leskov Is.	1911; 1964	———	Filchner 1923
2—Zavodoski	1819; 1964	1830	Fanning 1834
3—Protector Shoal	———	5—14 March 1962	Gass et al. 1963
4—Mount Hodson, Visokoi	1830	———	Fanning 1834
	1930; 1964	———	Kemp and Nelson 1931
5—Candlemas	1953	1953—4(?)	Holgate 1963
6—M. Michael (S. I)	1820; 1964	———	Holgate and Baker 1979
7—Bristol	1962	1935; 1956	Holgate and Baker 1979
8—Bellingshausen	Permanent	———	Holgate and Baker 1979
9—Thule	1962	———	Holgate 1963
BRANSFIELD RIFT			
1—Deception Is.	Permanent	1842; 1912; 1917	Gonzalez—Ferran et al. 1971
		4 Dic 1967 21 Feb 1969 12 Ago 1970	Baker et al. 1975
2—Penguin	1945; 1966	——— (?)	Tyrrell 1845; Gonzalez—Ferran and Katsui 1970; Birkenmager 1982
LARSEN RIFT			
1—Paulet	———	(?)<1000y.	Baker et al. 1973
2—Lindenberg (S. N.)	———	11 Dic 1893	Larsen 1894
3—Dallman (S. N.)	27 Ene 1982	———	Gonzalez—Ferran 1983
4—Murdoch (S. N.)	27 Ene 1982	———	Gonzalez—Ferran 1983
5—Christensen (S. N.)	11 Dic 1893	———	Larsen 1894
MARIE BYRD LAND			
1—Takahe	———	(?) Ash.	
2—Siple	———	18 Sep 1988	Le Masurier and Rex 1990
3—Hampton	Fumarolic ice tower	———	Le Masurier and Wade 1968 Gonzalez—Ferran and Gonzalez—Bonorino 1972
4—Waesche	———	(?) Ash.	Le Masurier and Wade 1968
5—Kauffman	1982	———	Le Masurierand Rex 1982
6—Berlin	Nov 1967—77	———	Gonzalez—Ferran and Gonzalez—Bonorino 1972 Le Masurier and Kawachi 1990
7—Webber N. (Hudson)	1974	(?) 1985	Rowley et al. 1990
HALLET AND VICTORIA LAND			
1—Melbourne	Fumarolic	(?) Tepha	Worner and Viereck 1990
2—Erebus	Permanet	Lava lake 82—86	Kyle 1986; Kaminuma 1988
BALLENEY ISLANDS			
1—Buckle Is.	———	1983 1899	Balleney 1839 Quartermain 1964

tica and the protection of the Antarctic environment has been discussed for some time.

1. Eruptions at Deception Island

This is a polygenetic caldera, associated with the southwestern part of the active Bransfield Rift (Fig. 2). Since the beginning of the historical record, there have been frequent eruptions at Deception Island, in particular along the interior rim of the caldera (Gonzalez-Ferran, 1987; Baker et al., 1975). Some of the first news about volcanic activity was reported by Wilkers (1845), who said that previously: "The whole south side of Deception Island appeared as if on fire". This event is believed to have occurred at the series of craters below Mount Kirkwod. Orheim (1972) suggested that there were a series of pyroclastic eruptions during the period 1912−17, based on the measurement of seasonal windblow dust layers in the ice. On December 4−7, 1967, about 2 km west from the Chilean Station, after intensive seismic activity, a freatomagmatic eruption began at three points in Telefone Bay, building a small tephra island in it, at the same time, there was an eruption from a maar crater near the shore. The Station was covered with a layer of more than 30 cm of tephra, producing a roof collapse. On that occasion, the Station was full of people. The volume of tephra ejected was estimated in approximately 57×10^6 m^3, its height was approximately 6,000 m (Vergara, 1967), and the plume of dust was expanded over the South Shetland Islands. A second phase of this eurptive cycle occurred on February 21, 1969, just at the backyard of the Chilean Station; fortunately, the personnel had left a few minutes before on board of the Piloto Pardo ship. The station was totally destroyed and covered by tephra and lahar. A few hours later, the lahar and tephra partially affected the British Station at Whaler Bay. A series of fissures opened in the ice on the west, facing the slopes of Mount Pond, and tephra emissions occurred from a

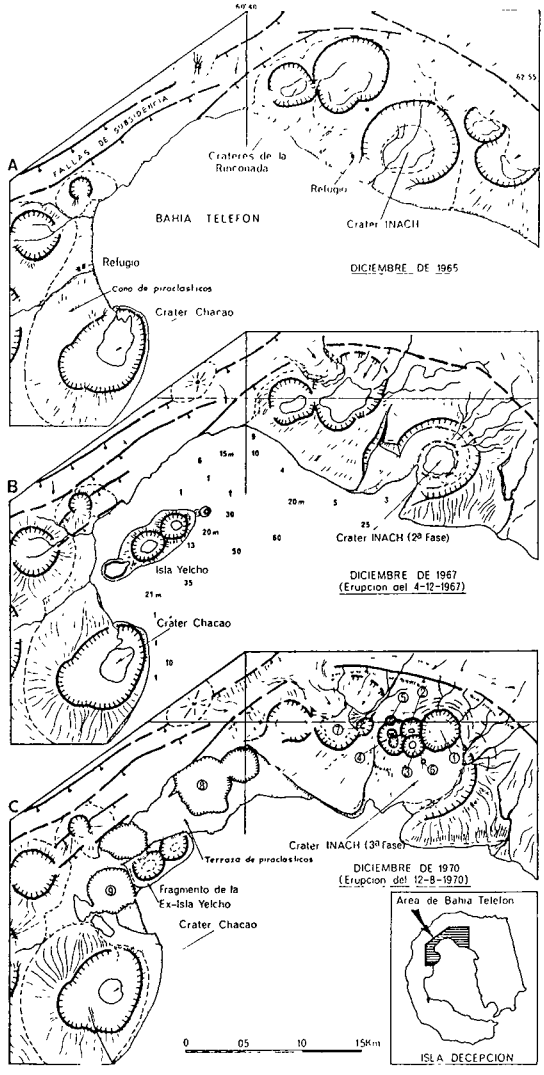

Fig. 2. Deception Island: strong morphological changes produced by the eruptions of 1967, 1969 and 1970. (After Gonzalez−Ferran et al., 1971).

number of craters along the fracture. Meltwater produced in this activity flooded down into Port Foster and lahars developed. The third and final phase of the present eruptive cycle, occurred on August 12, 1970. There was further activity along the northern edge of Telefone Bay, and a chain of new craters developed.

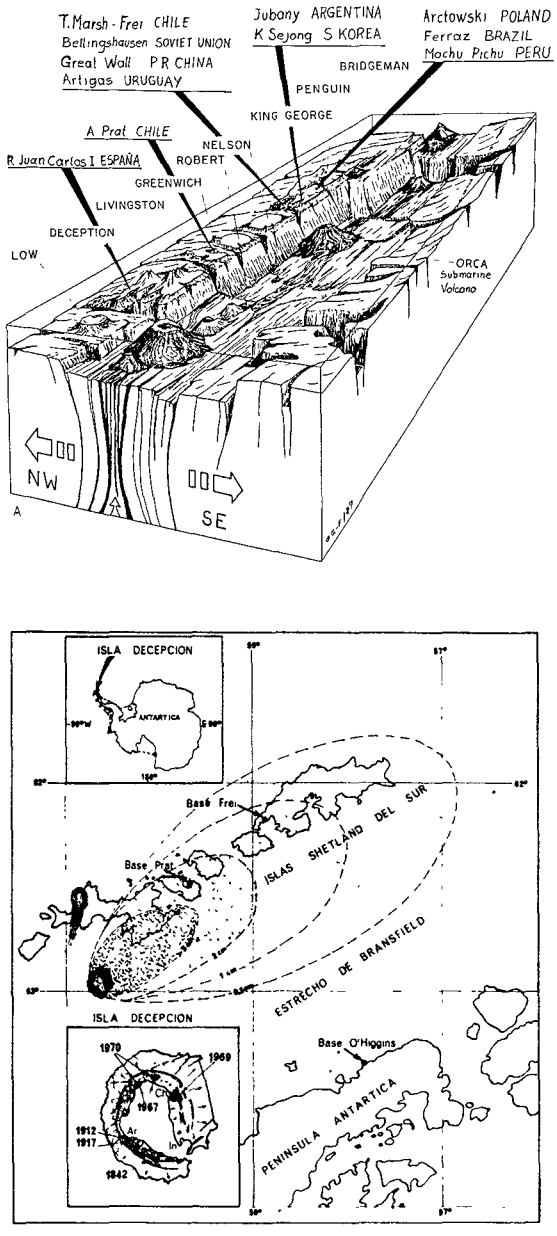

Fig. 3. A. Panoramic view of the active Bransfield Rift, South Shetland Islands and distribution of the Stations. B. Deception Island; isopach map of the tephra produced during the 1970 eruption.

A new strip of land was produced and the small island appearing in 1967 was incorporated within it (Fig. 2). The tephra fall covered all the South Shetland Islands. The ash-fall at the Chilean Station on Greenwich Island reached a thickness of 2 cm. Figure 3b shows the isopach map. The minimum volume of tephra was estimated at approximately 100×10^6 m^3. But the seismic activity continued. From time to time, the number of earthquakes and their magnitude increase. One of those, in February 1971 had a magnitude of 7.1, with its hipocenter near Deception Island, being probably associated with the magmatic activity at the Bransfield Rift.

2. Protector Shoal Volcano

This is a seamount located on the northern end of the South Sandwich Islands, 56km north west of Zavodowski Island. Its depth below sea level is 27 m. An eruption of this submarine volcano occurred after the strong earthquake of March 5, 1962, and later, on March 14, an extrusive pumice raft was encountered (Gass et al., 1963). The marine currents transported the mass of pumice around the Antarctic Continental Coast; it arrived at the South Shetland Islands coast, and also reached New Zealand about two years later.

3. Erebus Volcano

This is the main volcano of the Ross Island; one of the two presently active volcanoes in the McMurdo Volcanic Group, on the western margin of the Ross Sea. The most active volcano of Antarctica and the southernmost active volcano on Earth, contains a persistent convecting anorthoclase phonolite lava lake, which has frequent small Strombolian desgassing eruptions. An adjacent "active vent" has larger, less frequent Strombolian eruptions and occasionally throws bombs up to the height of 1 km above the vent (Kyle, 1986).

Submarine Volcanic Ridge, and Active Volcanism in the Bransfield Strait

A series of submarine volcanoes developed in association with the Bransfield Rift. Some of these emerged above sea level to form Deception, Penguin and Bridgeman Islands. There are at least ten volcanoes along the ridge (Fig. 3) spanning a distance of 300 km from Bridgeman to the submarine volcano southwest of Deception. Near Orca Seamount off the southern coast of King George Island, close to the entrance of Fildes Bay, is the largest submarine volcano in the area (Gonzalez-Ferran, 1990). Considering that the opening of Bransfield Strait and magmatism associated with rifting occurred during 2 Ma (Weaver et al., 1982; Gonzalez-Ferran and Katsui, 1970), and that historical activity has been recorded at Deception and Penguin Islands (Gonzalez-Ferran and Katsui, 1970), it can be estimated that volcanic activity along the Bransfield Strait is still in the process of development. New eruptions, both subaerial and submarine, could be recorded in the future at any of the volcanic centers shown on Figure. 3 or at other points associated with the rift.

Volcanic Risk Regions

There are two main RISK REGIONS in the Antarctic continent and they also represent the main door of entrance into it. They are Ross Island (McMurdo Station and others) and King George Island (Marsh Station and other 10 permanent stations), which also show a great concentration of scientific stations belonging to different countries; big logistic operational systems, ships and airport facilities, etc., all of them emplaced close to the active volcanic centers.

Figure 3 shows the situation of King George Island and the concentration of the stations along the active volcanic line as was never seen before. It is worthwhile remembering the just described eruptions, and the disaster they caused at the Chilean and British Stations, and to project what could happen today, if an eventual eruption surprised some of the many aircraft overflying the area.

Monitoring International Project

At present, each country having a station in the Southern Shetland area makes isolated and independent efforts to monitor the seismic and volcanic activity with very poor results. On this occasion I would like to propose a joint scientific and technological effort, in only one big project to develop the seismic network along the active rift, which would permit the detection in time of any volcanic reactivation, in order not only to acquire new scientific knowledge on it but also to give an opportunity alert to the stations, in order to reduce the percentage of vulnerability and mitigate the effects of the new natural process. This project is according to the International Decade for Reduction of Natural Hazard (IDRNH), agreed upon by the United Nations, and the International Council of Scientific Unions (ICSU) and also following the Antarctic Treaty and the SCAR's philosophy with relation to scientific co-operation and conservation of the Antarctic environment.

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