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SEISMICITY AROUND THE ANTARCTIC PENINSULA

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Abstract: Seismic activity in the vicinity of the South Shetland Islands, at the north tip of the Antarctic Peninsula, is very high compared with other regions of the Antarctic. A study of International Seismological Center data between 45°-70°W and 55°-72°S, covering the 1970-1990 time period, verifies this conclusion. Earthquakes are located along the South Scotia Ridge, the Shackleton Fracture Zone, the Hero Fracture Zone and the South Shetland Islands. The earthquakes in the South Shetland Islands are concentrated on Deception and Bridgeman Islands, both volcanic Islands on either side of the Bransfield Rift. No seismic evidence is recognized along the Bransfield Rift, and very little along the South Shetland Trench. It can be concluded that neither subduction nor rifting is active in this region at present.

1. Introduction

It was general knowledge before 1957, when the International Geophysical Year (IGY) started, that the whole of Antarctica was stable and only minor seismicity in the vicinity of the active volcano, Mount Erebus (77.6°S, 166.7°E), was to be expected (GUTENBERG and RICHTER, 1954). Permanent seismological stations have been established in the Antarctic since IGY (KAMINUMA, 1992), and are part of the dense world wide seismological network. Seismic activity in the Antarctic has been reported by several researchers (KAMINUMA and ISHIDA, 1971; ADAMS, 1972, 1982). The Antarctic continent and its surrounding Southern Ocean are divided into the following five regions in terms of seismicity: 1) intraplate low seismic region of the Southern Ocean, 2) the high seismic region around the South Shetland Islands at the tip of the Antarctic Peninsula, 3) the Antarctic Continent aseismic region, 4) the low seismic region at the edge of the continent, and 5) volcanic regions.

In this report, the seismic activity around the South Shetland Islands is discussed. The South Shetland Islands and the South Scotia Ridge are the most seismotectonically active areas in the Antarctic plate, presumably because of active volcanicity. The South Shetland Islands is thought to be a subduction zone where the Phoenix Plate (Drake Plate) is subducting along the South Shetland Trench.

2. Seismicity of the Antarctic

The background seismic activity in and around the Antarctic Continent will be briefly described in this section. Figure 1 shows epicenter locations of earthquakes in the

Antarctic which were compiled from the International Seismological Center (ISC) catalogue for the 1904–1991 period.

The following activity is identified in the figure: high seismic activity along the Antarctic plate boundaries, intraplate earthquakes in the Southern Ocean, the high seismic activity around the South Shetland Islands at the tip of the Antarctic Peninsula and earthquakes on the continent. The intraplate seismic activity in the Southern Ocean is very low, but the magnitudes of some intraplate earthquakes are larger than 6.0.

Four earthquakes for continental Antarctica are held in the ISC files from the early stage of Antarctic research. However, except for one event out of the four, no significant earthquakes were located on the Antarctic continent before the IGY because neither their exact locations nor their magnitudes were determined (ADAMS *et al.*, 1985). It is recognized in Fig. 1 that some earthquakes are located in Wilkes Land, though the magnitudes of most of them are unknown.

Eleven earthquakes, all less than magnitude 5.0, have been located by the world wide seismic network on the Antarctic Continent since the IGY as shown in Fig. 2 (KAMINUMA and ISHIDA, 1971; KAMINUMA, 1991). Four earthquakes out of the eleven were located around Deception Island, in the Antarctic Peninsula region. The details of the seismic activity around Deception Island will be discussed in Section 5.

The activity on the Antarctic Continent is very low, but some seismic events have been recorded. The magnitudes of the earthquakes located on the Antarctic Continent are less

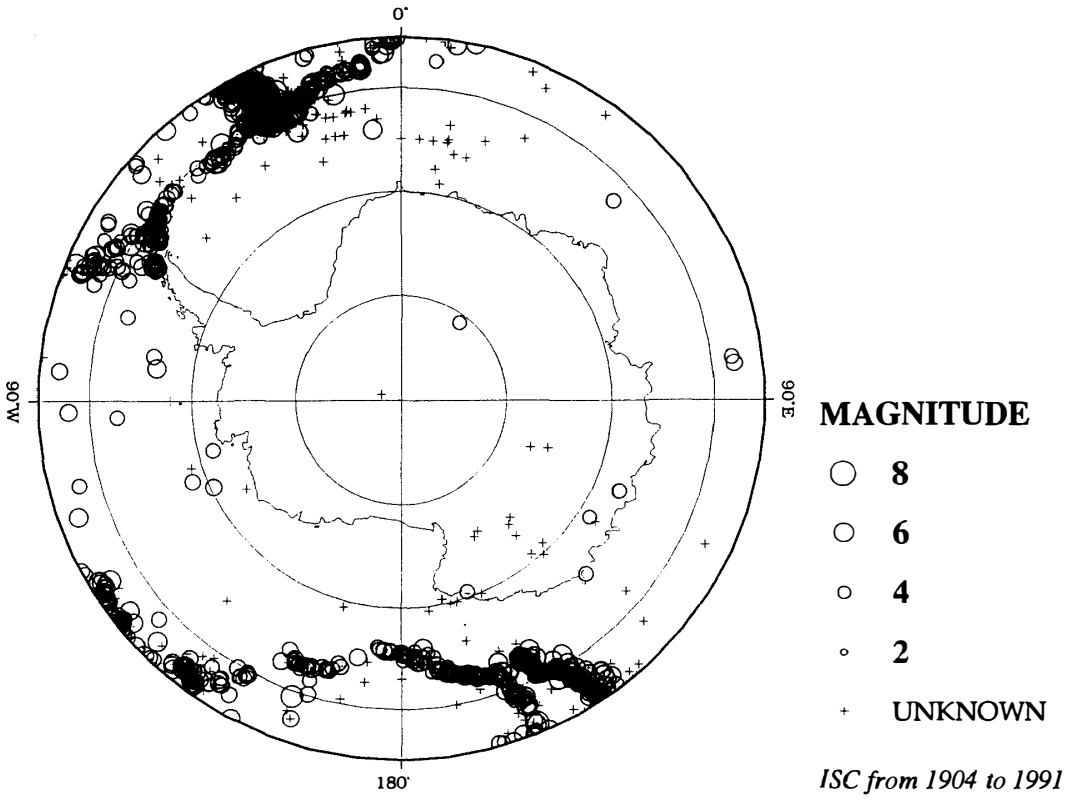

Fig. 1. Earthquake locations in the Antarctic for the period 1904–1991 determined by the International Seismological Center (ISC).

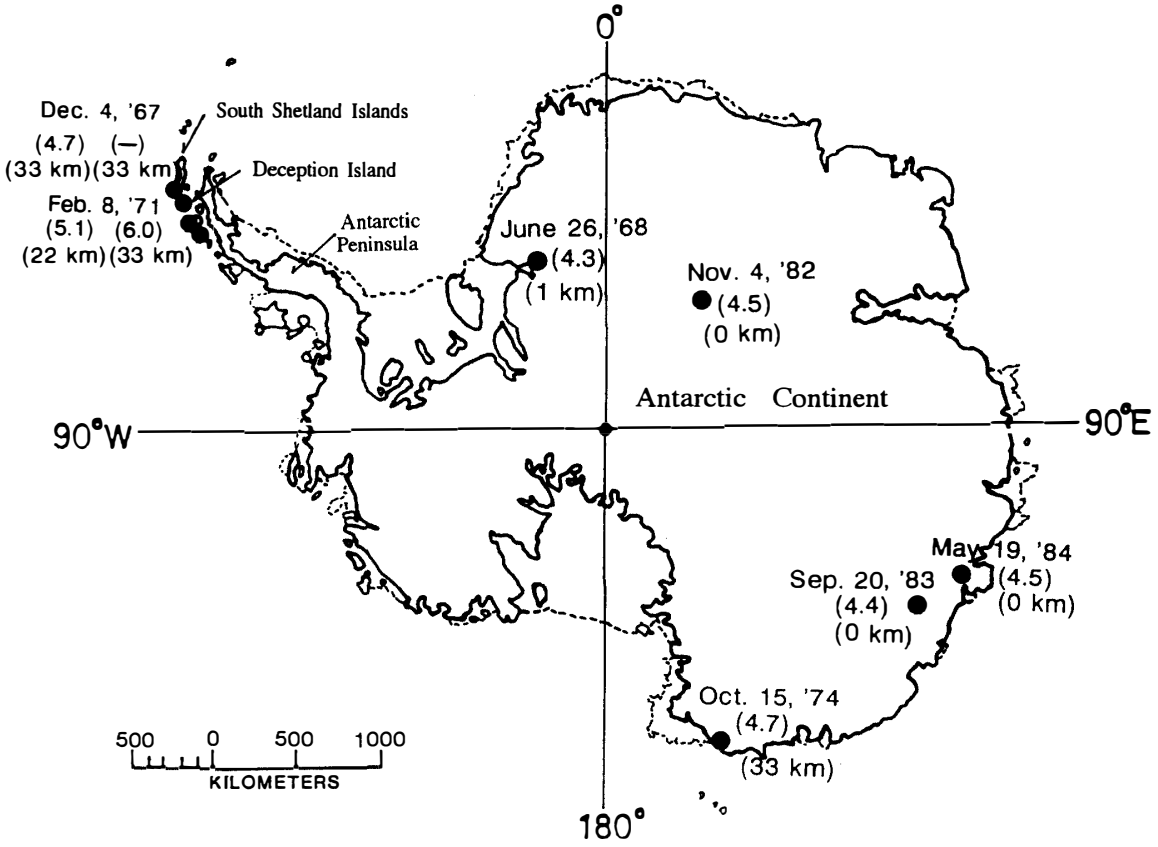

Fig. 2. Earthquake locations on the Antarctic Continent from 1960 to 1991. The occurrence dates are shown together with body-wave magnitude and focal depths in parenthesis.

than 5.0. The existence of such seismic activity does not alter the fact that Antarctica is a stable continent. Antarctica still has no large earthquakes and has lower seismicity than any other continent.

3. Seismic Network Around the Antarctic Peninsula

The activity recorded by seismic stations operating in the Antarctic were compiled by KAMINUMA (1992) according to the recommendation of the Working Group on Solid Earth Geophysics (WG/SFG) of the Scientific Committee on Antarctic Research (SCAR). Four seismic stations were operating in the Antarctic Peninsula region by the end of 1991 as shown in Fig. 3. However, three stations out of four are located on King George Island of the South Shetland Islands. Those are Arctowski of Poland, Great Wall of China and King Sejion of Korea. Each station has a three-component short period seismograph. A vertical-component short-period seismograph has been operated at Faraday Station of the UK. The abbreviation of the Faraday seismic station is AIA. All seismic stations are located in the islands, north-west of the Antarctic Peninsula; no seismic stations are operated on the Peninsula.

According to informal information from the U.S., a set of broadband digital seismo-

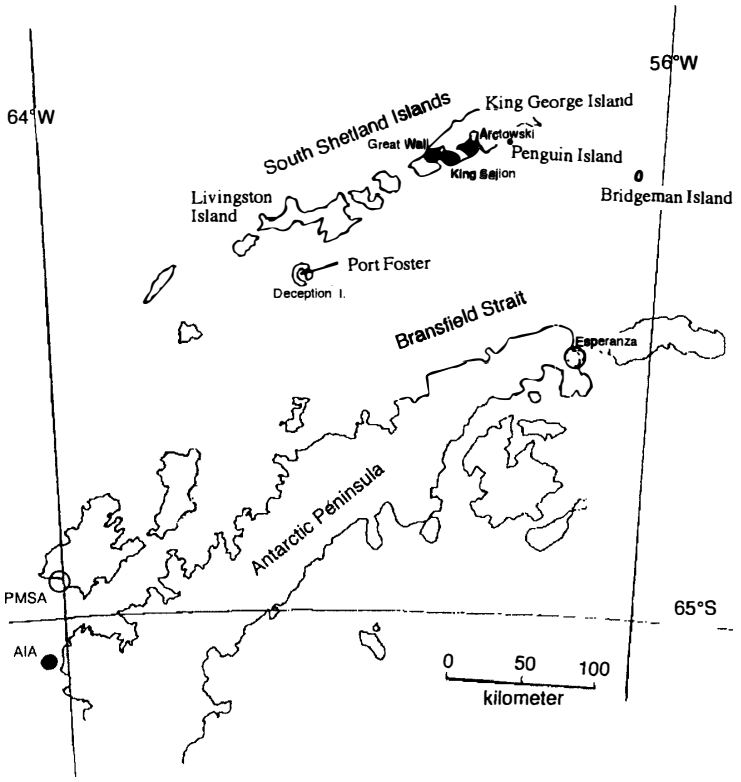

Fig. 3. Locations of seismic stations in the Antarctic Peninsula region.

graphs was installed at Palmer Station (64.7°S, 64.0°W: PMSA) in 1993. A three-component broadband seismograph was installed at Base Esperanza (63.4°S, 57.0°W) in a cooperative arangement with Argentine and Italy.

If these six seismic stations are in full operation and phase data are exchanged among the stations, the local small- and micro-seismic activities including earthquakes with magnitude less than 3 around the South Shetland Islands and the Bransfield Strait could be studied by using these seismic data.

4. Seismic Activity

In the tip of the Antarctic Peninsula region between 45°-70°W and 55°-72°S, 173 earthquakes were located by ISC during the 1916-1990 period. Magnitudes of these earthquakes are mostly larger than 4.0, although some magnitudes are undetermined. Thirty-six earthquakes out of 173 occurred before 1969 and 12 earthquakes out of the 36 events occurred before IGY when no Antarctic seismic stations were operating. Epicenter locations of 137 earthquakes for the 1970-1990 period are shown in Fig. 4. The focal depth of the earthquakes in Fig. 4 is mostly shallower than 50 km. During this period, there were only three earthquakes with focal depths between 50 and 100 km and only one event at a depth of 167 km, deeper than 100 km.

Earthquakes were located along the South Scotia Ridge, the Shackleton Fracture Zone, the Hero Fracture Zone and in the South Shetland Islands. Earthquakes located along the South Shetland Islands were concentrated in two areas of the Bransfield Strait:

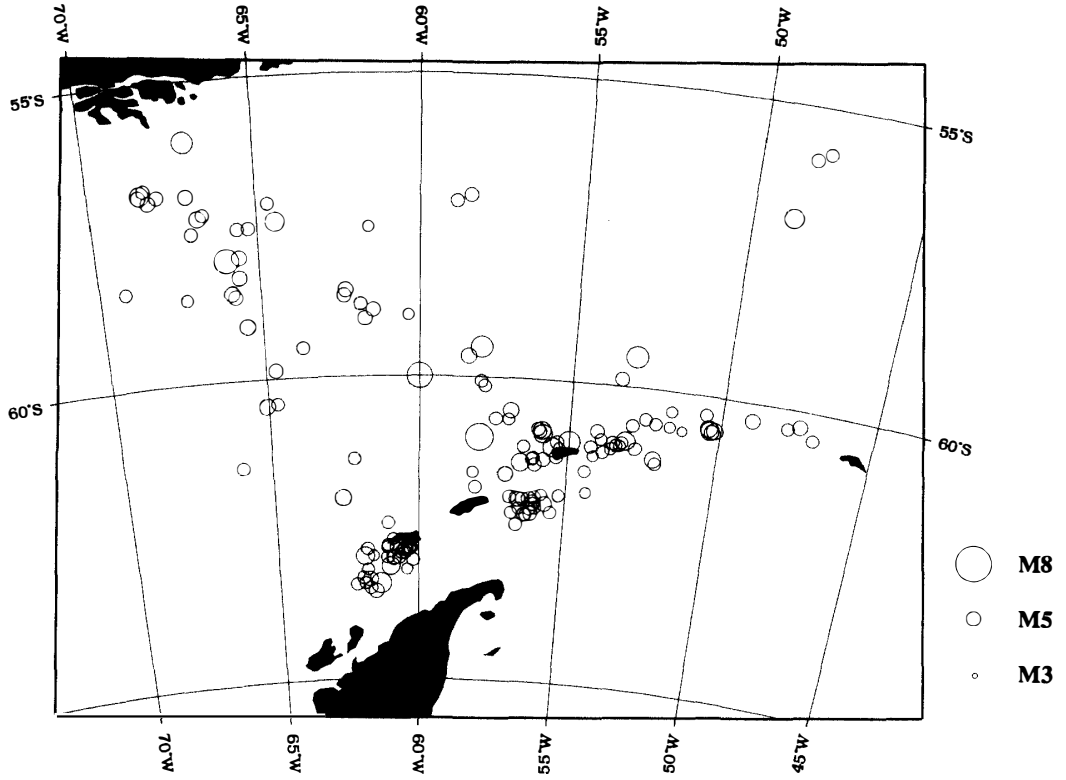

Fig. 4. Epicenter locations of earthquakes for the period 1970-1990 in the region 45-70° W, 55-72°S determined by ISC.

one is around Deception Island and the other is around Bridgeman Island (62.0°S, 56.7°W). Both islands are volcanoes. No eruption at Bridgeman Island has been observed; however, numerous records of fumarolic activity have been reported by whaling and sealing boats between 1821 and 1880.

A series of submarine volcanoes was reported by GONZALEZ-FERRAN (1991) in the Bransfield Strait. Some of them emerged above sea level to form Deception, Penguin and Bridgeman Islands. Earthquake locations are concentrated in the two volcanoes of Deception and Bridgeman Islands with no earthquakes located between the volcanic islands.

The South Shetland Trench located to the north of the South Shetland Islands is the only trench which is identified along the Antarctic Plate margin. However no earthquakes are located along this trench.

5. Seismic Activity Around Deception Island

Deception Island in Bransfield Strait is located at the southwestern end of the South Shetland Islands. It is a horseshoe-shaped island, 14 km long in the north-south direction and 13 km east-west. The sunken interior, Port Foster, is a caldera. Port Foster has been known by whalers and sealers as a good place for anchoring since the early 19th century. Probable eruptions were reported by explorers in 1842 and during the period 1912-1917 (BAKER, 1990).

Table 1. Locations of two large volcanic earthquakes in Deception Island.

Origin time	Location		Depth	M
1967. December 04				
19 h 00 m 22.6 s	63.0°S	60.5°W	33 km	4.7
20 28 30.5	63.2	60.3	33	

Table 2. Locations of two large earthquakes near Deception Island.

Origin time	Location		Depth	M
1971. February 08				
08 h 20 m 37.47 s	61.746°S	63.359°W	22.0 km	5.1
08 21 04.19	61.358	63.430	12.0	6.0

Big eruptions occurred near the shore on the north-northeast side of Port Foster on December 4, 1967. All stations on Deception Island were destroyed by the eruption and were evacuated. Two earthquakes accompanying the 1967 eruptions were located by the world wide seismic network (listed in Table 1).

The depth of both earthquakes, was constrained to be 33 km. This shows that both earthquakes were very shallow. The magnitude of the second event was not determined. This also means that the magnitude was probably less than 4. The DPE (Preliminary Determination of Earthquakes) card of the U.S. Coast and Geodetic Survey reports that these two epicenters are believed to be the first instrumentally located in the Antarctic region.

A series of volcanic activities occurred from February 1969 to August 1970, and some earthquakes with magnitude around 4 were located.

In February 1971, two earthquakes near Deception Island occurred in a short time as shown in Table 2. They were located by ISC, and had magnitudes of 5.1 and 6.0. The second event is the only earthquake with magnitude 6.0 or above, ever recorded around the Antarctic Continent. The event with magnitude 5.1 is the 2nd biggest.

Seismic observations and geophysical surveys have been carried out on Deception Island by the Spanish National Program for Antarctic Research during every January-February, since the 1986-87 austral field season (VILA *et al.*, 1992; ORTIZ *et al.*, 1992). Six seismic stations were temporarily established during that time. About 1000 events per month occurred with a released seismic energy of about 3.0×10^{13} erg/day. Deception Island seems to be seismotectonically active.

6. Discussion and Conclusion

The region at the tip of the Antarctic Peninsula, especially the South Shetland Trench, is considered to be the last remnant of a subduction zone that has been active along the Pacific margin of Gondwana (PANKHURST, 1990). The South Shetland Trench represents the only trench topography recognized clearly along the Antarctic Plate margin. A schematic tectonic map showing the setting of the South Shetland Trench is shown in Fig. 5 (original: PELAYO and WIENS, 1989). The trench was formed by subduction as a result

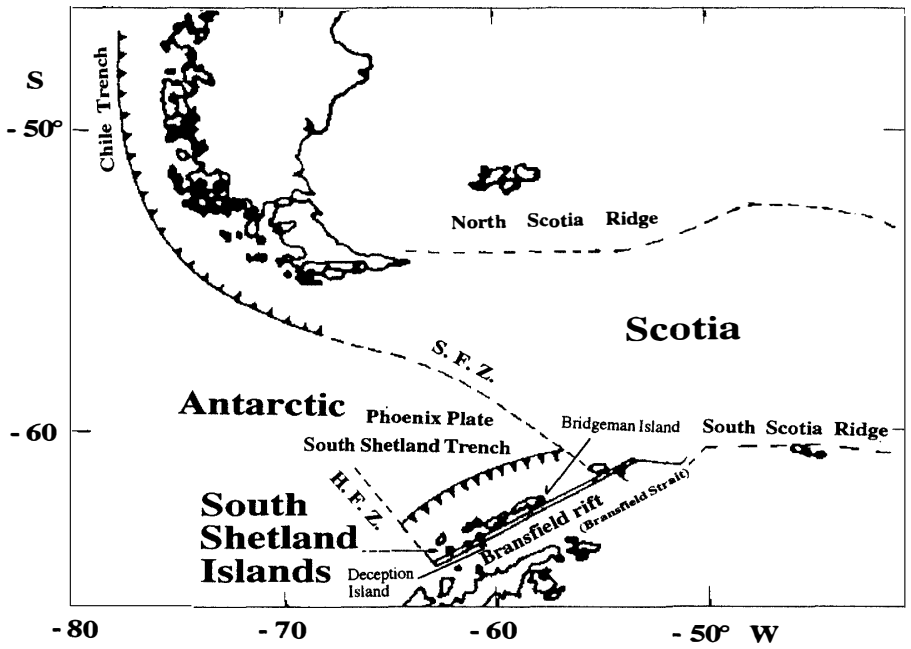

Fig. 5. A schematic tectonic map around the South Shetland Islands. S.F.Z. denotes the Shakleton Fracture Zone and H.F.Z. the Hero Fracture Zone (original: PALAYO and WIENSIENS, 1989).

of a northwest-southeastward migration of the Phoenix Plate. The Phoenix Plate is a micro plate in the Drake Passage bounded by the Shakleton Fracture Zone and the Hero Fracture Zone.

Two volcanic islands, Deception Island and Bridgeman Island, and some submarine volcanoes are located along the South Shetland Islands in the Bransfield Strait. The chain of volcanoes defines the Bransfield Rift. A micro plate named Bransfield Plate is formed by extension along Bransfield Rift in Bransfield Strait. If active extension in the Bransfield Strait exists, convergence between the South Shetland Islands and the ocean floor south-east of the trench is required.

Marine geophysical surveys were conducted to study tectonic deformation of the oceanic basement and overlying sediments in the region around the South Shetland Islands. Marine Geophysical Survey by KIM and JIN (1994) and KIM *et al.* (1994) addressed the following seismotectonic circumstances:

1) Is the Phoenix Plate still subducting ?
2) Is the Bransfield Rift active ?

The seismicity around the South Shetland Trench is very low, and very few deeper earthquakes occurred. There dose not appear to be any seismic evidence that the Phoenix plate is subducting.

Earthquakes are located around Deception and Bridgeman Islands at both ends of the Bransfield rift. However, no seismic activity is recognized along the rift, and no seismic evidence exists for extension. On the basis of the seismic evidence reported by ISC, it is concluded that neither subduction of the Phoenix Plate nor rifting of the Bransfield Rift is active at the present time.

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