

## Seismic Activity Around McMurdo Sound in Antarctica

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南極マクマードサウンド周辺の地震活動

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**要旨:** 日本, アメリカ, ニューゼーランド3国共同事業として, ドライバレー掘削プロジェクト (DVDP) が 1971-1976 年の夏のシーズン, アメリカのマクマード基地を中心に行われた. このプロジェクトの一環として, 1974-75, 75-76 年のシーズンに微小地震の観測を行った.

観測は, マクマード基地北東域のアライバル・ハイツで3週間, オブザベーション・ヒル北方麓で1カ月, ドライバレーのティラー谷で10日, バンダ基地で3週間, 実施した.

マクマード基地は火山島であるロス島の南西端に位置し, 活火山エレブスの火口から 30 km 離れている. マクマード基地付近での観測からは, 1日に1個程度の頻度で微小地震が発生していることが明らかになった. また大陸にあるドライバレーでの観測では, 2日に1個程度の発生頻度であった. この二つの事実からマクマードサウンド周辺の地震活動は, 2日に1個程度の割合で微小地震が発生し, 火山地域ではそれに重なりさらに同程度の割合で微小地震が起こるものと推定される.

**Abstract:** For the purpose of observing micro earthquakes around the McMurdo Sound area and volcanic earthquakes around Mt. Erebus on Ross Island, in Antarctica, seismological observations were carried out in the austral summer seasons of 1974-75 and 1975-76, as one of the research programs of the Dry Valley Drilling Project (DVDP) which was carried out by scientists from Japan, New Zealand and the United States.

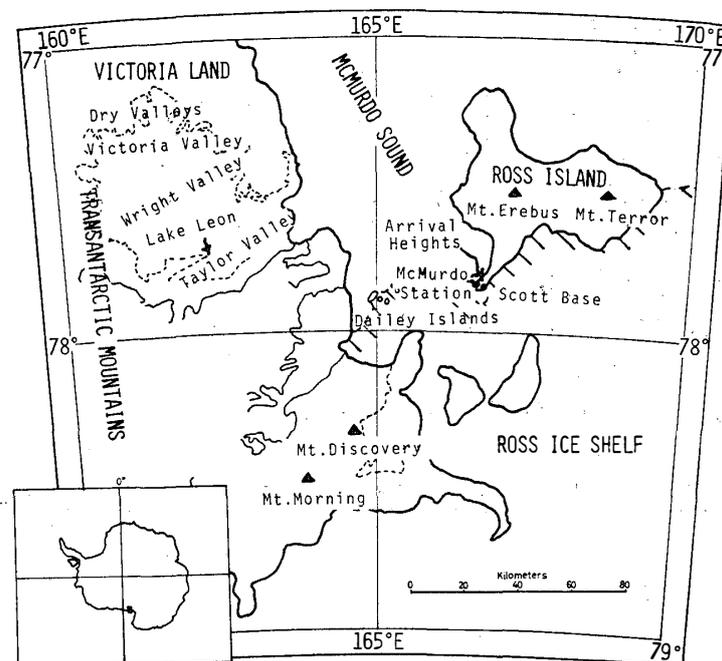
The sites and duration of observations are as follows: 1) Arrival Heights, McMurdo Station (three weeks in 1974-75); 2) Lake Leon, Taylor Valley, one of the dry valleys in Victoria Land (10 days in 1974-75); 3) Northern foot of Observation Hill, McMurdo Station (one month in 1975-76). The micro seismic activity around McMurdo Station obtained from the observations is about one earthquake per day, and that in the Taylor Valley is about 0.5.

Background seismicity around the McMurdo Sound area is estimated to be one micro earthquake every two days. In addition to this background seismicity, one earthquake occurs in every two days in the volcanic area around McMurdo Station.

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## 1. Introduction

The McMurdo Sound area is located as shown in Fig. 1 between the Antarctic continent and Ross Island, in the middle of the western part of the Ross Sea. Ross Island is volcanic, with one active volcano, Mt. Erebus. Some extinct volcanoes, Mt. Discovery, Mt. Morning, the Dailey Islands, etc., also are located in the southern part of McMurdo Sound. The Transantarctic Mountains trend from north to south on the west side of McMurdo Sound.



*Fig. 1. Local map of McMurdo Sound. Lake Leon is a small lake in the middle of Taylor Valley. Arrival Heights located in the north-eastern part of McMurdo Station.*

Near the eastern end of the Transantarctic Mountains are several snow free valleys, called the Dry Valleys, with an area of 4,000 km<sup>2</sup>. The valleys contain warm and saline lakes. The reasons for the formation of the dry valleys are very important and interesting problems in the Antarctic earth science. For the purpose of solving these problems, the Dry Valley Drilling Project (DVDP) was carried out by scientists from Japan, New Zealand and the United States in the austral summer seasons from 1971 to 1976. Fifteen holes were drilled on Ross Island, in McMurdo Sound, and in Taylor, Wright and Victoria Dry Valleys.

For the purpose of observing micro earthquakes around the McMurdo Sound area and volcanic earthquakes around Mt. Erebus, seismological observations were carried out in the summer seasons of 1974-75 and 1975-76, as one of the research

programs of DVDP.

The first seismological observations in the McMurdo Sound area and in Antarctica were made by the Scott Antarctic Expedition in 1902–03. The observations were carried out for several months and 136 shocks were recorded, but none of these shocks originated in Antarctica (GUTENBERG and RICHTER, 1954).

More than ten seismological stations have been established in Antarctica since International Geophysical Year (IGY) in 1957. The seismological station at New Zealand's Scott Base which is located on Hut Point Peninsula, Ross Island, was established in 1957. Scott Base is now one of branch stations of the World Wide Seismological Station Network.

During the summer season of 1969, seismological observation was carried out at New Zealand's Vanda Station in Wright Valley, about 120 km WNW of Scott Base. Using the seismograms obtained at Vanda Station and Scott Base, ADAMS (1969) determined the locations of nine small earthquakes on the Victoria Land Coast in the north part of the Dry Valleys.

The present paper reports on the micro seismicity of the McMurdo Sound area on the basis of observations at McMurdo Station and at Lake Leon in Taylor Valley in the summer seasons of 1974–75 and 1975–76.

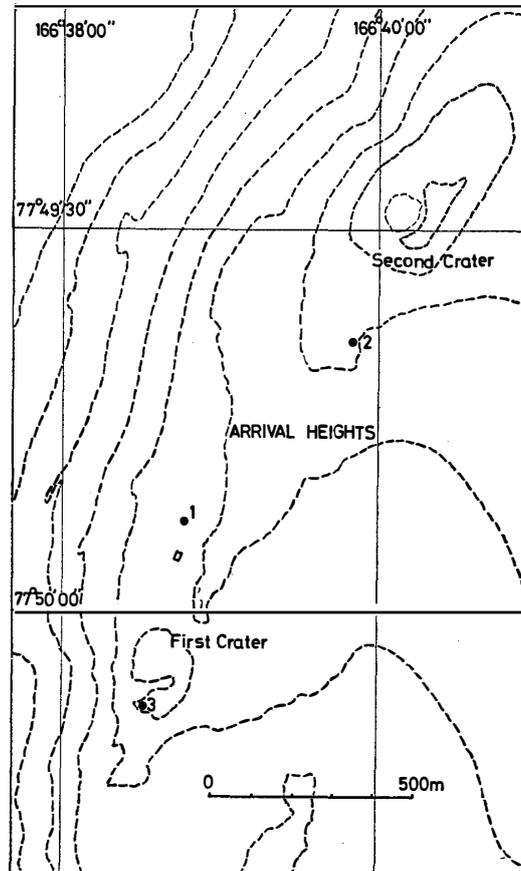
## 2. Observation at McMurdo Station in 1974–75

Tripartite seismological observations were made at Arrival Heights near McMurdo Station located on Hut Point Peninsula during three weeks in 1974–75 using a cassette data recorder. The snow free area at McMurdo Station is not suitable for seismological observation because the area is covered with thick layers of volcanic ejecta, mainly lappilli, and the rock area near the station is too narrow for installing tripartite network. Arrival Heights consists of two small craters, First and Second Craters. Wide rock area for the tripartite observation was not available at Arrival Heights, however this area is the best available site for observations, in the vicinity of McMurdo Station.

Three seismographs were installed, one near the observation hut of Scott Base for aeronomy on Arrival Heights, another near Second Crater, and the third near First Crater (Fig. 2). The period of the pendulum of the seismograph was 1.0 second. A cassette recorder with four channels for three amplifiers and one crystal clock was set within a small trunk with dimensions  $60 \times 40 \times 20$  cm. Eight 3-volt batteries were also set in the trunk to drive the recorder, the amplifiers and the crystal clock. This trunk covered with a styrofoam box was installed outside near the entrance of the observation hut. The observation system was used with a magnification of 100,000.

The observation was disturbed frequently by strong noises owing to windy weather

Fig. 2. The locations of seismographs installed on Arrival Heights. The numbers 1, 2 and 3 are the observation points.



conditions and the high magnification of the recording system. The cassette data recorder sometimes did not operate in the low temperatures, and data for only eight days were available. The determination of the hypocenter locations of these earthquakes was not successful because the seismograph near First Crater recorded large seismic tremor throughout the observation period.

Some earthquakes and ice shocks were recorded by the observation network, and distinction of these two were easy from their wave forms (KAMINUMA, 1971; KAMINUMA and ISHIDA, 1971).

The time sequence of earthquake occurrence is shown in Fig. 3. The solid line shows the period of the observation and the dashed line shows that of the extreme micro seismic activity. Eight micro earthquakes with P-S times less than 10 seconds were identified during the nine days from 24 December 1974 through 2 January 1975. The real observation period was eight days because periods of the extreme micro seismic activity as shown by dashed lines in Fig. 3 were excluded from the record. The magnitudes of the earthquakes were between 0 and 1.

No small and/or minor earthquakes were recorded. The seismicity around the McMurdo Station area is considered to be about one micro earthquake per day.

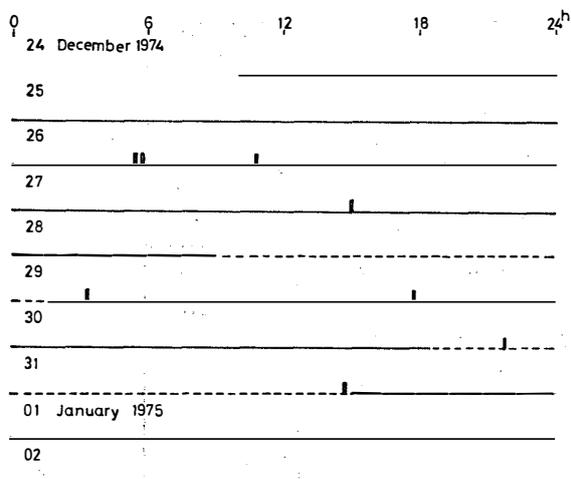


Fig. 3. The time sequence of earthquake occurrence observed at Arrival Heights of McMurdo from December 24, 1974 to January 2, 1975. Solid columns show the occurrence of earthquakes and the dashed line shows the period of extreme seismic activity.

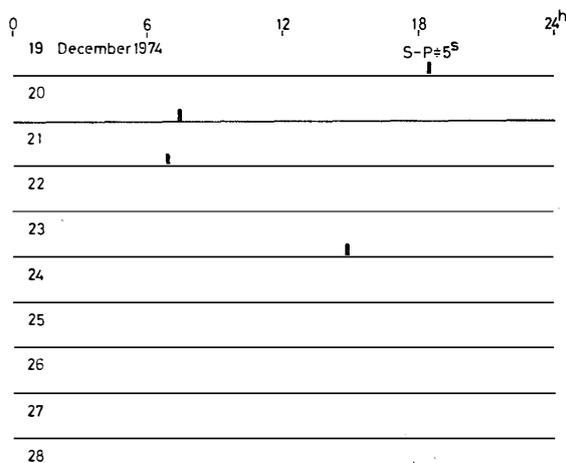


Fig. 4. The time sequence of earthquake occurrence observed at Lake Leon, Taylor Valley from December 19 to 28, 1974. Solid columns show the occurrence of earthquakes.

### 3. Observation at Lake Leon, Taylor Valley in 1974–75

Seismological observations at Lake Leon, Taylor Valley, one of the dry valleys in Victoria Land, were carried out from 19 to 28 December 1974 (Fig. 1). One vertical seismograph and a cassette data recorder of four channels, three different magnifications (5,000, 20,000 and 50,000) and one time mark, were used for the recording system. This instrument is the similar one which had been used as a seabottom seismograph (SHIMAMURA and ASADA, 1974).

The seismograph was installed on basement rock of granite gneiss near the DVDP No. 12 drill hole near the Lake Leon. The recorder, a crystal clock, and batteries were installed in a tent at the drilling site. The crystal clock and batteries were covered with styrofoam boxes. The temperatures inside the tent under good weather conditions in the Antarctic summer season were always higher than 0°C, because the sun shines all the day long. The observation was carried out without any troubles. Four micro earthquakes with magnitudes from 0–1 were recorded during 8.5 days, as shown in Fig. 4. One of the four earthquakes had a P–S time of 5 seconds. The P–S times of the others were not read because the S phases could not be clearly identified. No small and/or minor earthquakes were recorded.

The seismicity around Taylor Valley was approximately one micro earthquake every two days.

#### 4. Observation at McMurdo Station in 1975-76

To confirm the results obtained in the summer season of 1974-75, seismological observations were carried out at McMurdo Station in 1975-76. Three short period seismographs were also installed on the northern foot of Observation Hill in McMurdo Station. However it was not tripartite observations but only the similar observation of one point; seismographs were set very close to each other, on one line with a length of 200 m. This distribution of seismographs was necessary because of conditions unsuitable for seismic observation around McMurdo Station.

A pen recorder with four channels using chart recording paper was installed in the Thiel Earth Sciences Laboratory at McMurdo Station. The amplifiers which were used in the previous season were also used in the recording system.

To avoid artificial ground noise in the day time, observations were carried out only at night, usually from 20:30 to 07:30. The system used a magnification of 120,000 at 10 Hz of frequency and a recording paper speed of 1 mm/s. Thirteen earthquakes with P-S times less than 10 seconds were recorded between 13 November and 19 December, 1975. The total time of observation, except the period of high seismic noise, was 302 hours, or 12.6 days.

The list of earthquakes which were recorded is given in Table 1. Most of the earthquakes observed at McMurdo were also recognized on the seismogram at Scott Base, even though their amplitudes were very small. The magnification of the seismogram at Scott Base, located 2 km east of McMurdo, was 50,000 till 14 December, 1975, and 25,000 after that. As is already well known (e.g. HATHERTON and ORR,

Table 1. List of earthquakes recorded at McMurdo Station from November to December, 1975.

Date	Time (LT)	P-S	Remarks
	h m s		
Nov. 15	03 07 30	3.9 <sup>s</sup>	
18	03 27 25	—	
20	01 04 31	—	
25	05 44 12.5	4.6	
26	04 15 26.7	3.8	
27	00 36 42.6	—	
Dec. 7	23 30 46	3.9	
8	07 01 05	2.4	
	23 48 28	4.7	Not recorded at Scott Base
9	01 41 08.9	3.3	
16	06 52 30.5	3.2	
17	00 51 59.2	3.2	
18	02 31 00	3.6	Not recorded at Scott Base

1959; MURAUCHI, 1962), micro seismic activity in the marginal area of the Antarctic continent becomes high in the summer season, when the amount of sea ice decreases. Therefore, seismological observations at stations located in the marginal area of the Antarctic continent are operated with low magnifications in the summer season.

The seismicity of this observation period was one earthquake per day. This seismicity is the same as that recorded in the previous season, as was described in Section 2. Therefore, seismic activity in the steady state around McMurdo Station is considered to be about one micro earthquake per day.

The P-S times of ten of the thirteen earthquakes were measured. The frequency of P-S times is shown in Fig. 5. P-S times of seven earthquakes were 3.0–3.9, and those of two earthquakes were 4.0–4.9. If the earthquakes are assumed to have originated around Mt. Erebus, their epicenters were located mainly in the southern foot of Mt. Erebus, about 20–25 km north of McMurdo Station.

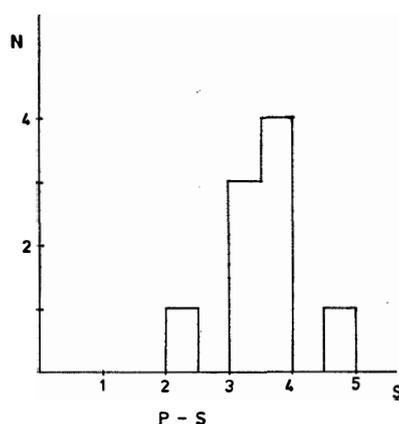


Fig. 5. Frequency of P-S times of earthquakes recorded by the observation at McMurdo Station from November 13 to December 19, 1975.

## 5. Discussion and Conclusion

The micro seismic activity around McMurdo Station is about one earthquake per day, and that in the Taylor Valley is about 0.5. The magnification of the instrument used at McMurdo Station is about two times greater than that at Lake Leon. However, considering the higher seismic noise around McMurdo Station, the observations at both areas are thought to be detecting earthquakes of the same scale. Therefore, micro seismic activity around the McMurdo Station area is higher than that around the Dry Valleys. Background seismicity around the McMurdo Sound area is estimated from these observations to be one micro earthquake every two days. In addition to this background seismicity, one earthquake occurs in every two days in the volcanic area around McMurdo Station.

Stems and/or white smokes were discontinuously emitted from the summit crater of Mt. Erebus through the seismological observation period at McMurdo Station. A lava lake inside the crater and some steam eruptions were observed by a

joint party of New Zealand and French expedition in 1974 and by a New Zealand party in 1975. No large eruptions occurred during the period of these two observations.

There is no close relationship between the high seismicity around McMurdo Station and the volcanic activity of Mt. Erebus, though the seismological observation points at McMurdo Station are only about 30 km from the active crater of Mt. Erebus. The higher seismicity in the volcanic area is caused by structural weakness of the upper crust.

Seismicity around Syowa Station, which is located in the marginal zone of the east Antarctic shield, was estimated by TAKAHASHI *et al.* (1975) to be 10 micro earthquakes per year. Seismicity around McMurdo Sound is some ten times greater than that around Syowa Station. This fact may indicate that, in general, seismicity in West Antarctica and Ross-Weddell Graben is higher than that in East Antarctica, as given in Table 2.

Table 2. Seismicity.

Station	Magnification of instrument	Number of earthquakes
McMurdo (1974-75)	100,000	1.0 per day
(1975-76)	120,000	0.9 per day
Lake Leon	50,000	0.5 per day
Syowa Station	50,000	10 per year

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