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LOCAL EARTHQUAKE ACTIVITY AROUND SYOWA STATION, ANTARCTICA

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Abstract: The Japanese Antarctic Station, Syowa (69°S, 39°E), is located at the edge of the east Antarctic shield. Seismic observations at Syowa Station were started in 1959. Phase readings of earthquakes have been published by National Institute of Polar Research once a year since 1968, as one of the Data Report Series. Nine local earthquakes were detected empirically on short-period seismograms at Syowa Station in 1990–1996 on the basis of long term records of many different types of events. The seismicity during that period was very low compared with that in 1987–89 when local earthquake locations were determined by the tripartite seismic array. Magnitudes of the nine earthquakes ranged from 0.1 to 1.4. Locations of four earthquakes out of nine are determined by a single station method to be in the Lützow-Holm Bay and its northeastern coast area.

key words: seismicity, local earthquakes, Syowa Station, intermittent activity, epicenter location

1. Introduction

Syowa Station (69°S, 39°E) was established for the International Geophysical Year (IGY) in January 1957. It was general seismological knowledge by the IGY that no extreme earthquakes except in the volcanic regions occurred in the Antarctic (GUTENBERG and RICHTER, 1954). Though the seismological observations at Syowa Station were initiated with vertical component short period seismographs in 1959, starting in 1967 phase readings have been reported to the USCGS to help determine earthquake locations using the worldwide seismic network (KAMINUMA, 1969, 1976). At that stage, seismological observations at Syowa Station began with three-component long and short period seismographs.

Though the Antarctic is generally an aseismic region, some relatively significant earthquakes have occurred in the Antarctic continent. Earthquakes with magnitude larger than 4.0 and some local events with magnitude less than 3 have been located (KAMINUMA and ISHIDA, 1971; ADAMS, 1969, 1972, 1982; ADAMS *et al.*, 1985; KAMINUMA, 1976, 1990). However, though seismic stations in the Antarctic have been operated as a part of the worldwide seismic network, no detailed studies of local events have been made.

A seismic array with a tripartite network was established at Syowa Station in 1987 and the observations continued until 1989 (AKAMATSU *et al.*, 1988, 1989; KAMINUMA and AKAMATSU, 1992). The local seismic activity around Syowa Station was analyzed using the seismic data from this network. Micro and/or ultra-micro earthquake activities were recognized during the three year period 1987–1989.

In this paper, we report on local seismic activity around Syowa Station recorded since 1990, after terminating the local seismic array observations. Local events were detected on the three-component short period (1 Hz) seismometers with maximum magnification of 10000 at 1 Hz (NOGI *et al.*, 1997). The local seismic activities in 1990–1996 were lower than those recognized during the three year period 1987–1989.

2. Detection of Local Earthquakes

There are different kinds of seismic events aside from natural earthquakes recorded on seismograms at Syowa Station: sea icequakes, seismic tremors with duration of some ten seconds caused by ice calving at the edge of the Antarctic ice sheet, etc. Based on the data from the tripartite array in 1987–1989, local events around Syowa Station are characterized by the clear onset of *P* and *S* phases with *S-P* times mostly less than 30 s, and the epicenters of the those events are located in Lützow-Holm Bay and along the coast. We can detect local earthquakes on seismograms at Syowa Station empirically by their waveforms. In this paper, local events are defined as events with clear *P* and *S* phases and *S-P* times less than 30 s.

To verify local earthquakes, four persons examined seismograms and selected local

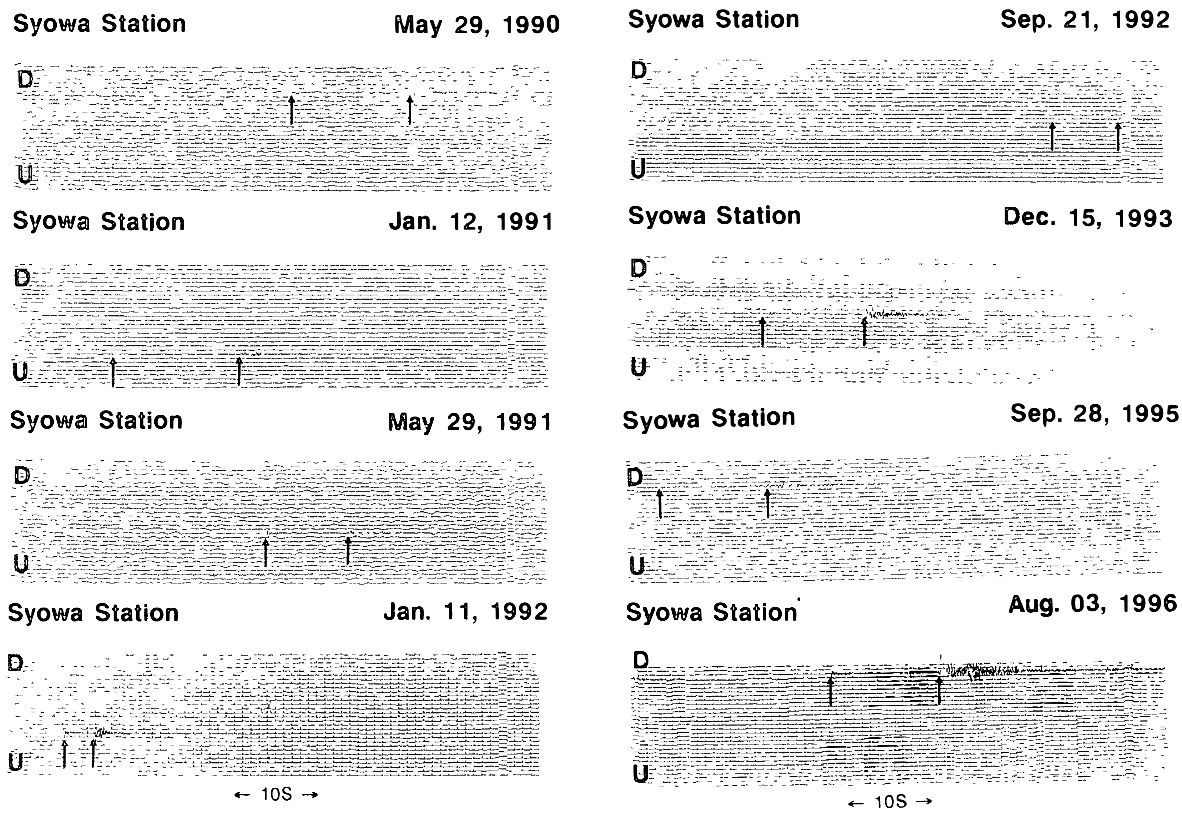

Fig. 1. Vertical components of short period seismograms of local earthquakes recorded at Syowa Station. The first and the second arrows show P and S phases, respectively.

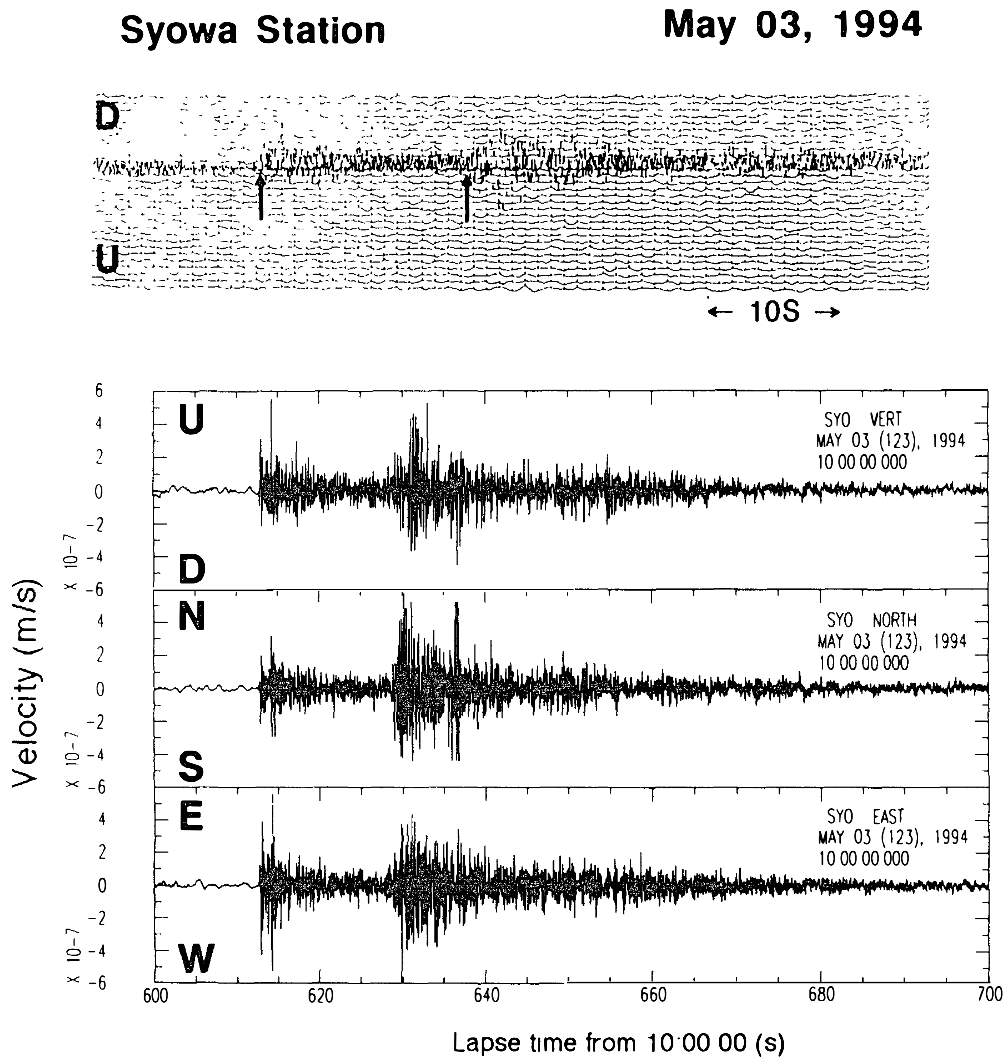

Fig. 2. Seismograms of the event on May 03, 1994. The vertical component of short period (upper) and three component digital seismograms.

events separately. The first two phase readers selected about 60 events collected during 1990–1996. Six months later, we reexamined the events to establish objectivity in identifying the local events. Nine events selected as local events around Syowa Station are listed in Table 1 with *S-P* times. The seismograms of the vertical component of the eight events are shown in Fig. 1. Figure 2 shows the three component digital seismograms and the vertical component of the short period seismogram of the event on May 03, 1994. This event was not counted as a local event by KAMINUMA and KANAO (1997) because the event has long duration and high frequency wave forms. As shown in Fig. 2, however, it is clear from the digital three component seismograms that the event is a local event having clear *P* and *S* phases and *S-P* time of 16.2 S. This earthquake was the biggest one from 1990 to 1996, with magnitude 1.4. The relatively large magnitude caused the longer duration. The magnitude of the earthquakes, in Table 1, was determined using the JMA method because the HES seismograph was of velocity type.

Table 1. List of local events recorded at SYO.

Date	Phase	Arrival time	*P-S* time	Propagating angle	Magnitude
1990 May 29	iP	07 h 36 m 33.5 s	14.4 s		
	eS	07 h 36 m 47.9 s			
1990 Jan. 12	iP	01 h 51 m 12.4 s	15.2 s		
	eS	01 h 51 m 27.6s			
1991 May 29	iP	01 h 17 m 30.8 s	9.9 s		
	iS	01 h 17m 40.7 s			
1992 Jan. 11	iP	12 h 49 m 07.1 s	3.7 s		
	iS	12 h 49 m 10.8 s			
1992 Sep. 21	iP	16h 14 m 51.8 s	7.2 s		
	iS	16h 14 m 59.0 s			
1993 Dec. 15	iP	04 h 13 m 16.5 s	12.3 s	303°	0.6
	iS	04 h 13 m 28.8 s			
1994 May 03	iP	10 h 10 m 13.3 s	16.2 s	60°	1.4
	iS	10 h 10 m 29.5 s			
1995 Sep. 28	eP	08 h 06 m 04.0 s	13.0 s	309°	−0.4
	eS	08 h 06 m 17.0 s			
1996 Aug. 03	iP	14 h 32 m 24.2 s	13.2 s	52°	1.1
	iS	14 h 32 m 37.4 s			

3. Variation of Annual Frequency

Figure 3 shows the annual frequency of local earthquakes detected at Syowa Station from 1972 to 1996. The annual frequencies up to 1990 were reported by KAMINUMA and AKAMATSU (1992). The arrows at the tops of the columns corresponding to 1972, 1973 and 1987 in Fig. 3 indicate that the exact numbers must be larger than those indicated in the figure because the actual observation time during the three years was less than 12 months. As the magnifications of seismographs have changed about 10% through the observation period, the figure does not reflect exact numbers of local earthquakes which occurred in each year. However, the figure at least provides information about local seismic activity around Syowa Station since the 1970's.

KAMINUMA and AKAMATSU (1992) reported six local earthquakes in 1990. As the result of detailed examination of the six events by four readers as described in the previous section, it is concluded that only one local earthquake occurred in 1990.

The local seismic activity during 1990–1996 was lower than that during 1987–1989 when the tripartite seismic network was in operation. The low activity in 1990–1996 is consistent with the idea that the local seismic activity around Syowa Station is intermittent and 1987–1989 was a high activity period (KAMINUMA and AKAMATSU, 1992).

4. Earthquake Locations

Attempts were made to locate earthquake epicenters of the local events using the first particle motion of the initial phase and *S-P* time. As the first arrival phases of the

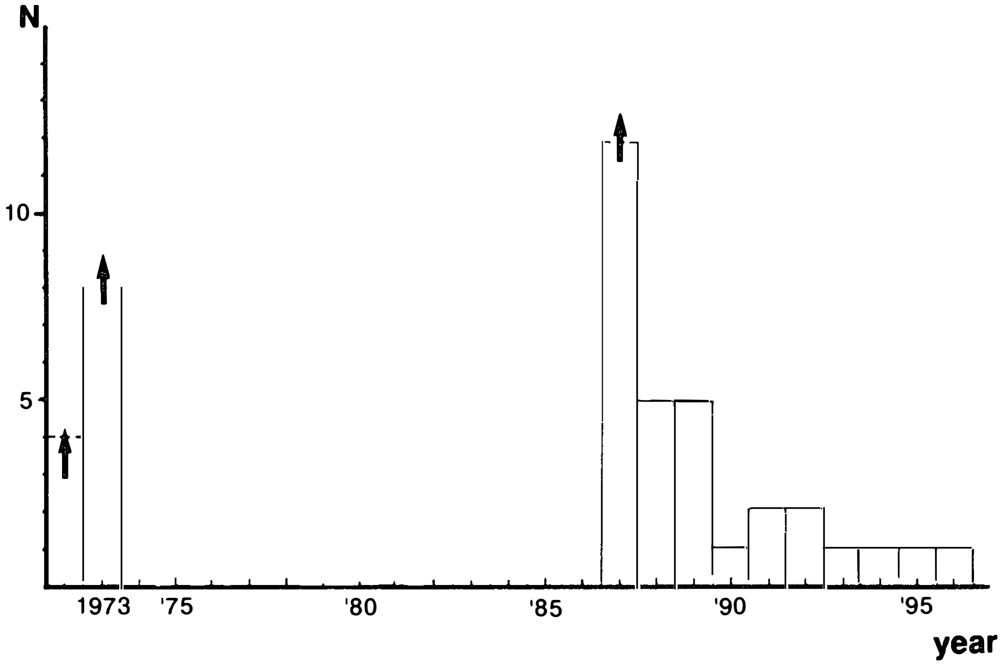

Fig. 3. Annual frequency of local earthquakes observed at Syowa Station. Arrows show the possibility that the exact number is larger than that shown.

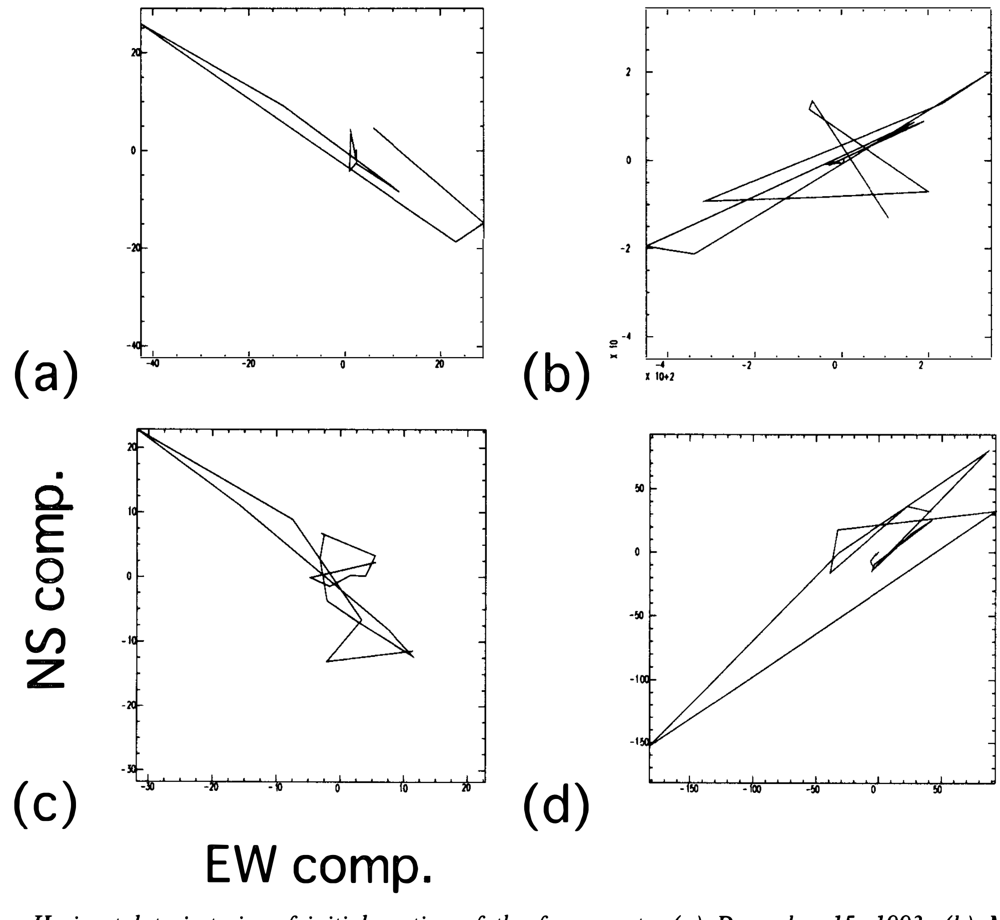

Fig. 4a. Horizontal trajectories of initial motion of the four events; (a) December 15, 1993, (b) May 03, 1994, (c) September 28, 1995 and (d) August 03, 1996. Vertical trajectories of initial motion are projected on the vertical plane including the epicenter and Syowa Station.

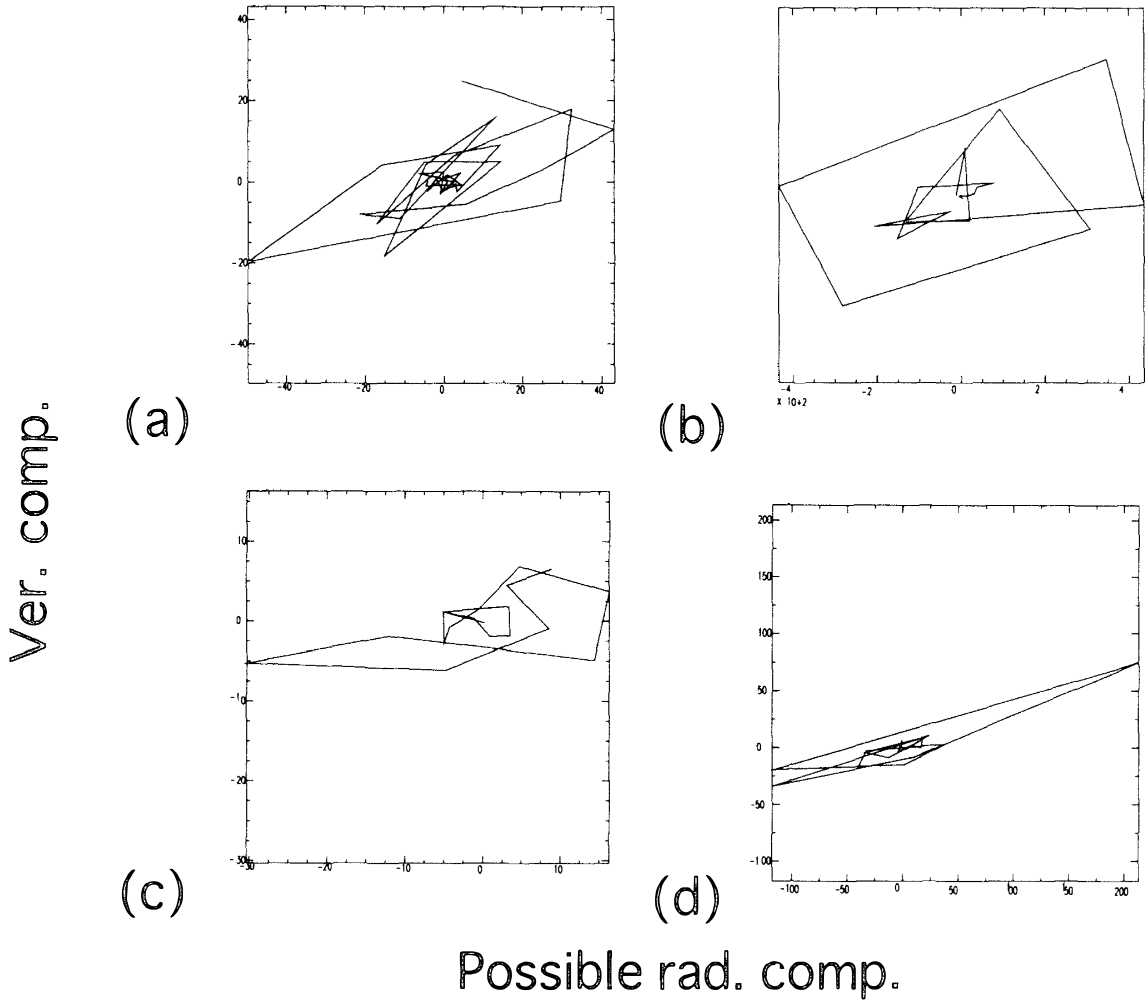

Fig. 4b. Same as Fig. 4a but for vertical trajectories.

local events are considered to be the direct *P* phases, the propagating directions and incidence angles of the seismic waves were estimated by considering particle motions of the first arrival phases of three orthogonal components using digital seismograms. Four earthquakes out of nine were located by this method.

Figure 4a, b shows the horizontal and vertical trajectories of initial motion of the four events. The propagating directions were determined by the horizontal trajectories as shown in Fig. 4a. The incidence angles were determined by the vertical trajectories, which were projected on a vertical plane including the epicenter and the station as shown in Fig. 4b. The propagating directions to Syowa Station are listed in Table 1.

Epicentral distance was calculated by Oomori's formula using 6.8 km/s as Oomori's constant. This constant was estimated from the local crustal structure ($Vp=6.2$ km/s, $Vp/Vs=1.95$) by IKAMI *et al.* (1983). Figure 5b shows the epicenter locations of four local earthquakes determined by a single station. Locations of the four earthquakes seem to be reasonable estimated from the previous earthquake locations shown in Fig. 5a (KAMINUMA and AKAMATSU, 1992).

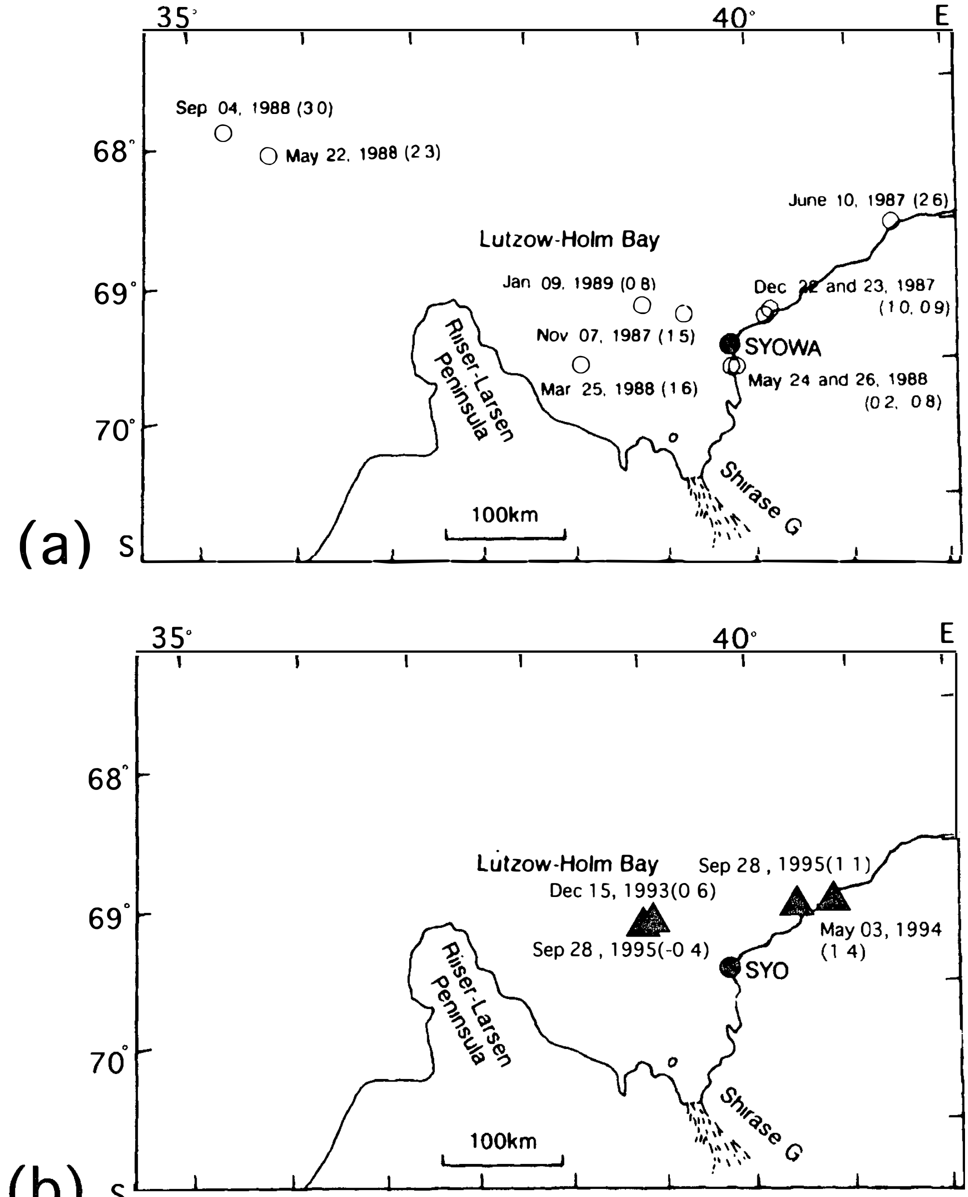

Fig. 5. Local earthquake locations around Syowa Station with magnitude. The earthquakes in 1987–89 were located by a seismic array (upper) and those in 1990–96 were determined from a single station (lower).

5. Discussion and Conclusion

Another three events which looked like local earthquakes were recorded on the seismograms of the short period seismographs at Syowa Station. Their vertical components are shown in Fig. 6 and event information is listed in Table 2 with their durations.

The event on May 26, 1994 was not located by the worldwide seismic network. However, that event looks like a teleseism, because it has a longer duration of 2 min and the period of initial phase of 0.5–0.7 s is too long for a local event.

It is a possibility that two events overlapped to make the event on October 22, 1995. The first part seems to be a local event with *S-P* time of 12.6 s and the later one could be

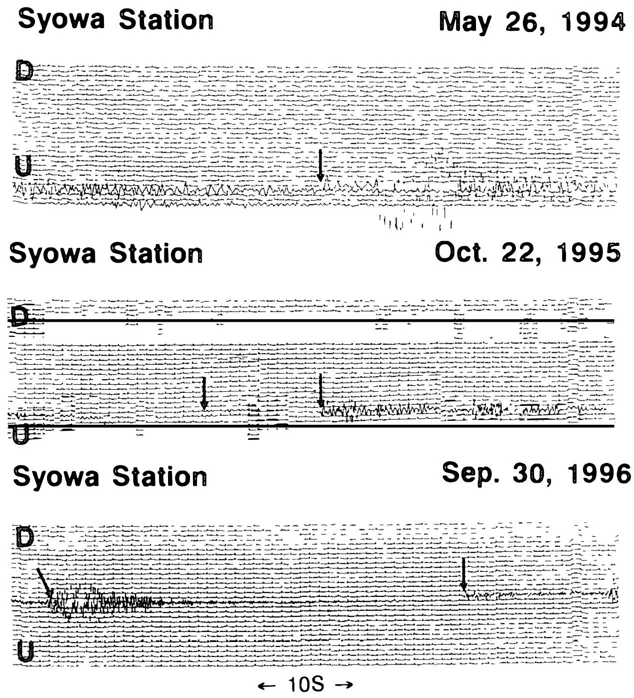

Fig. 6. Vertical components of seismograms corresponding to local events. The first arrow shows the initial phase of each event, the second phase seems to be the S phase.

Table 2. List of events.

Date	First phase	Arrival time	Duration time
1994 May 26	iP	00h 25m 33.0s	1m 50s
1995 Oct. 22	iP	16h 23m 21.1s	1m 02s
1996 Sep. 30	iP	04h 16m 04.5s	58s

an ice shock considering its waveform with high frequency. Therefore this event is not counted as a local earthquake in this paper.

The event on September 30, 1996 seems to be a local event, if it is identified as a single event. However, the *S* phase part has a higher frequency waveform than the initial phase part. Therefore the event might consist of two separate events. The estimated *S* phase part must be an ice shock.

As described above there is the possibility of other local events, as listed in Table 2 and shown in Fig. 6 during 1990–1996. The local seismic frequency around Syowa Station, during the seven years, was very low compared to the previous three years when the tripartite seismic network was in operation.

The teleseism detection capability at Syowa Station in 1987–1993 was studied by KANAO and KAMINUMA (1995). Although the detection capability was not high in 1987–1989 compared with other periods, high seismicity was recorded during that period. There was therefore no relation between the high and low detection capability and high local seismicity. It is clear that the number of local seismic events was larger in 1987–1989 and smaller in 1990–1996. This activity is considered to be associated with the crustal uplift after deglaciation which KAMINUMA and others (KAMINUMA and AKAMATSU, 1992; KAMINUMA, 1996; KAMINUMA and KIMURA, 1997) have explained as an intermittent phenomenon.

As the data are accumulating, it is expected to become possible to estimate stress accumulation related to glacial rebound from seismic events in the near future.

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