**RESEARCH ARTICLE**

# Kaitoku Seamount and the Mystery Cloud of 9 April 1984

Daniel A. Walker, Charles S. McCreery, Firmin J. Oliveira

Abstract. *On 9 April 1984, commercial airlines enroute from Tokyo, Japan, to Anchorage, Alaska, reported an unusual mushroom-shaped cloud at about 38.5°N, 146.0°E. On 8 and 9 April the intensity of volcanism from Kaitoku Seamount (26.0°N, 140.8°E), as indicated by T-phase recordings on an array of ocean bottom hydrophones, reached a maximum level and then declined rapidly. An examination was made of the possible relation of the cloud to eruptions of Kaitoku through an analysis of pilot depositions, satellite photos, wind charts, signal strengths and spectra of known man-made underwater explosions, as well as ascent rates of volcanic plumes and cumulonimbus clouds.*

On 9 April 1984, crews of three separate commercial airliners en route from Tokyo to Anchorage, Alaska, observed a gigantic mushroom-like cloud 180 miles off the coast of Japan at approximately 38.5°N, 146.0°E (Fig. 1). It was described as moving rapidly up and away from a stratiform layer of clouds at about 4300 meters (14,000 feet) eventually reaching a maximum altitude of about 18,000 m and a diameter of 320 kilometers. Although the explosion of a nuclear submarine seemed possible, none of the passenger or cargo planes examined in Anchorage showed any signs of radioactivity. No fireball or flash was observed. Nor were there any unusual effects on flight instrumentation. Also, dust collected from the scene by an F-4 Phantom fighter-bomber deployed by the Air Self-Defense Force of Japan showed no abnormal levels of radioactivity (*1–5*).

Another means of testing an explosion hypothesis (conventional or nuclear) is provided by recordings from an array of hydrophones located near Wake Island (Fig. 1). This array consists of eleven hydrophones, six on the ocean floor in a 40-km pentagonal arrangement (one of the elements is at the center of the pentagon) and five in the SOFAR (sound fixing and ranging) channel at three sites spanning 300 km. Data from eight of these eleven hydrophones have been recorded on a computer-controlled digital tape system almost continuously since September 1982. Two of the hydrophones are simultaneously monitored on drum recorders so that the data may be easily evaluated on a daily basis. The sensitivity of the instruments, which are monitored on Wake Island, the great efficiency of sound transmission in the world's oceans, and the relative proximity of the array to the source of any presumed underwater explosion make it unlikely that such an event could escape detection.

*Evidence from the Wake hydrophone array.* The drum recordings were searched for significant events in the hours and days preceding the reported sightings [approximately 14 to 15 hours universal time (UT)]. Continuously running spectrograms were also made for the 20 hours preceding the sightings. In neither the time nor frequency domain could a single prominent event be found that originated north and west of the array. Instead, the most conspicuous feature was a swarm of T-phases (Figs. 2 and 3) originating north and west of the array. We found that the swarm started around 14 or 13 March (there are no data for 13 March) and terminated around 15 April. Figure 4 shows the estimated number of these T-phases from the drum recordings for 1 March through 30 April. [Had specially filtered playbacks of digital tapes rather than the drum recordings been used (their use was not justified because of costs), many more T-phases would have been observed.] These observations and considerations are consistent with those of the Réseau Sismique Polynésien stations in Tahiti. These stations reported more than 500 signals from 25 March through 30 April; 300 were observed between 2 and 9 April (*6*). The arrival times of the most prominent T-phases at all of the hydrophones in the array restricts the direction of the source of the T-phases to bearings within the 2-second contour of Fig. 1. Theoretical T-phase arrival times across the array, based on a propagation velocity of 1.48 km/sec (*7*), differ on the average by less than 2 seconds from the corresponding observed arrival times for any source located within that contour. Mean observed values used in computing the standard deviations were obtained from the arrival times of six T-phases with especially distinct onsets at all of the hydrophones.

We attempted to obtain independent confirmation of the source location from other seismic arrivals [that is, Po/So phases (*8*)] but could find none at appropriate times preceding the strongest T-phases or those T's with large signal-to-noise ratios. Preliminary listings of earthquakes by the National Earthquake Information Service (NEIS) indicate no earthquakes within the 2-second contour during the swarm. (Most earthquakes reported by NEIS in the Mariana through Bonin portion of the circum-Pacific arc produce observable Po/So phases at Wake. In fact, the Wake Island array often records Po/So phases from earthquakes in this area that are not reported by NEIS.) Figure 3 shows a comparison of the character of these swarm-associated T-phases with the T-phases of earthquakes reported from the same general area (Fig. 3). SOFAR recordings (Fig. 3, phone 20) of T-phases associated with the swarm are impulsive and decay rapidly, whereas similarly recorded T-phases associated with earthquakes are less impulsive and decay more slowly. We then showed that the swarm-type T-phases are related to a submarine volcanic eruption, an event that was confirmed by eyewitness accounts. We used the designation "submarine volcanic eruption" for the swarm-type T-phase in Fig. 3, 5, and 6 because of its importance even though there is no certainty that an actual outpouring of material was associated with the particular T-phase chosen for these figures—nor, for that matter, with any of the several hundred other T-phases observed.

Spectrograms and spectra for the T-phases in Fig. 3 and for a T-phase from a man-made underwater explosion of unknown origin (*9*) are shown in Figs. 5 and 6, respectively. The swarm-type T-phase

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resembles the T-phase from the underwater explosion more closely than it resembles the earthquake T-phase (Figs. 5 and 6). Swarms of strong, impulsive T-phases of short duration with weak or nonexistent seismic arrivals have been reported (*10, 11*). Such activity has been attributed to submarine volcanism and confirmed by eyewitness accounts of eruptions (*12*). Visually confirmed sequences originated at the Myojin volcano (31.9°N, 139.9°E) near Tori-shima at 30.7°N, 139.8°E, and near Farallon de Pajaros at 20.4°N, 144.8°E (Fig. 1). All of these volcanoes have long eruptive histories and are listed in *Volcanoes of the World* (*13*). Myojin is classified as a submarine volcano, and Tori-shima and Farallon de Pajaros are listed as stratovolcanoes with eruptive submarine flanks.

From the preceding considerations, it is reasonable to suggest that the source of the T-phase storm may be submarine volcanism, probably located in that portion of the circum-Pacific arc intersected by the 2-second contours. Known volcanoes in this region are at 27.2°N, 140.9°E (Nishino-shima); 26.1°N, 144.5°E (unnamed); and 26.0°N, 140.8°E (Kaitoku Seamount) (Fig. 1). Of these, the most certain candidate is Kaitoku. Evidence is provided by the following narrative (*14*).

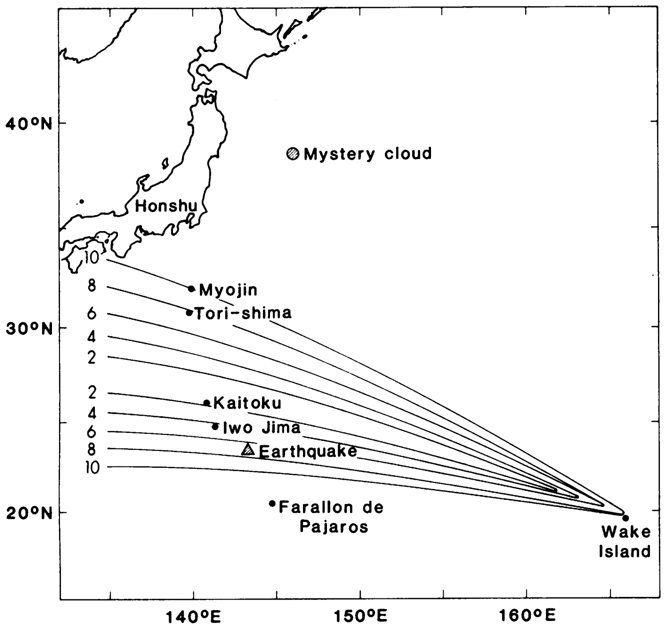



Fig. 1. Map showing the locations of the mystery cloud, Wake Island, some of the volcanoes south of Honshu in the Bonin, Volcano, and Mariana islands region, and an earthquake epicenter. Contours of standard deviations in seconds are shown for the location of the T-phase source for the swarm of March and April of 1984 (see text for further explanation).

> On 7 March [1984] at 1230, the crew of a Japan Maritime Safety Agency (JMSA) transport plane flying about 130 km N of Iwo Jima observed a fan-shaped zone of discolored seawater that extended about 25 km WSW from a submarine vent. The maximum width of the discolored zone was about 9 km. A helicopter from the base at Iwo Jima flew over the area shortly thereafter, and its crew estimated that the extent of the reddish-brown water was roughly as large as Iwo Jima Island (about 5 by 8 km). The next morning, JMSA personnel observed continuous submarine eruptive activity. Gray or yellowish-brown water was ejected every 10 minutes, and waves spread outward from the vents. The sea colors included gray, white, yellowish-brown, and reddish-brown. The JMSA observers saw neither plumes nor floating ejecta, although small white plumes and rocks or reefs were seen during a flight by the Japan Maritime Self-Defense Force (JMSDF) at about noon the same day. On 12 March, personnel aboard a JMSDF patrol plane again saw floating material, and a plume about 100 m above sea level. Only discoloration was found during a JMSA flight 13 March. As of the 13th, no new island had been observed at the eruption site. The activity was located near the site of an eruption reported in 1543 at 26.00°N, 140.77°E.

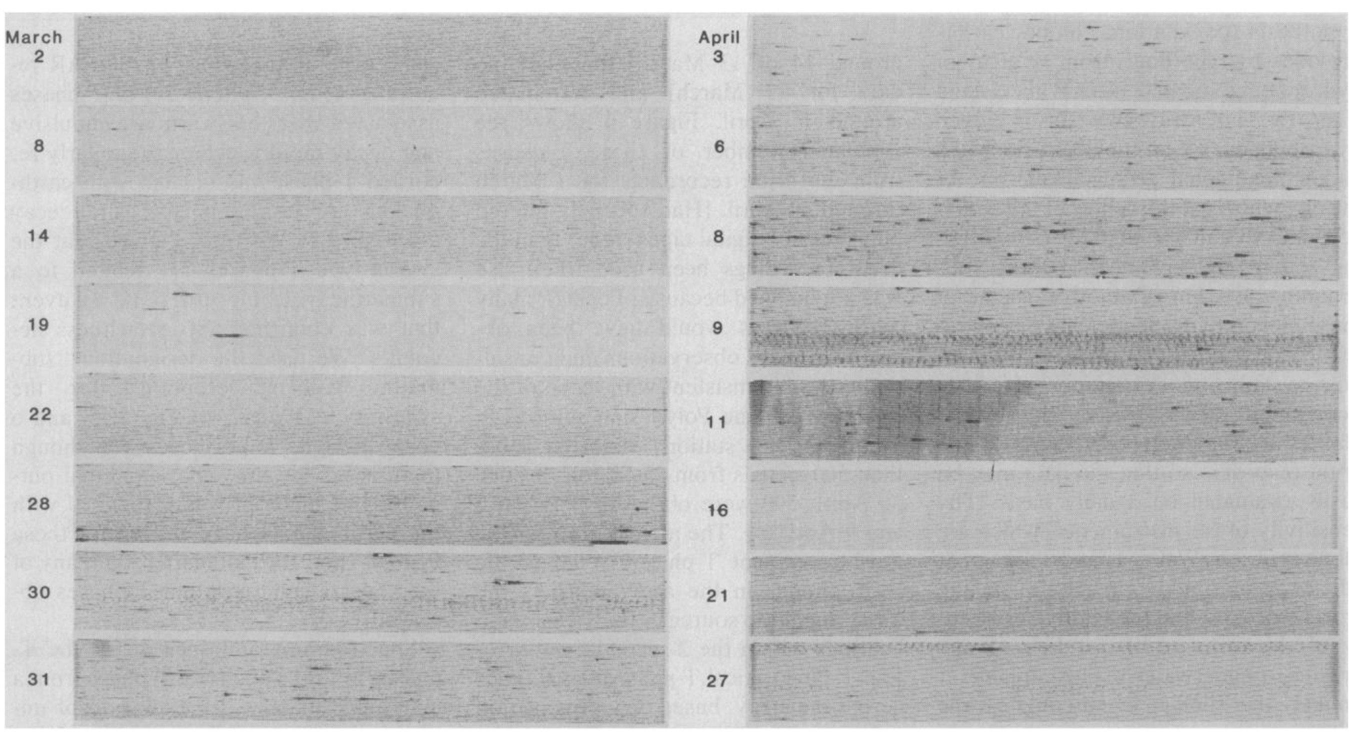



Fig. 2. Samples of hydrophone drum recordings from 1 March through 30 April 1984. Time increases from left to right and from top to bottom. Each recording is for a 24-hour period (48 horizontal traces) beginning around 0500 hours UT on the date indicated. Minute marks appear as vertical bands. A swarm of arrivals, T-phases from Kaitoku Seamount, reach their highest level around 8 April. Additional phenomena, more readily apparent on the full-sized originals of these and other recordings, include ground arrivals from distant earthquakes and underground explosions, ship noise, underwater explosions, biological noise, and wind- and storm-generated noise.

The histogram in Fig. 4 shows that some T-phase activity was observed at the time (7 through 12 March) of these visual observations. This level of activity is extremely low compared to that which followed, especially from 26 March through 14 April. The highest levels occurred on 31 March and 8 April, with the amplitudes of T-phases on 8 April being significantly larger than those observed on 31 March (Fig. 2). Was this high level of activity just 1 day before the sightings of the mystery cloud a coincidence?

*Did Kaitoku produce the mystery cloud*? A cloud that caused the concern of experienced flight crews can reasonably be considered to be very unusual. The captain of one of the airliners, a veteran of 41 years, immediately issued a Mayday alert to Anchorage International Flight Service and put his crew on oxygen as a precautionary measure (*1*). Later he stated that he had "never seen anything like it except in newsreels and films" (*3*). Similarly, the occurrence of large T-phase swarms over a 3- to 4-week period is very unusual. Since operation of the upgraded system at Wake began in September 1980, only one other suspected swarm was observed on the visible recordings. It occurred on 9 July 1983, lasted for only 26 hours, and had its origin along an azimuth north of Kaitoku.

Since Kaitoku generated a plume on 12 March, it seems possible that the greatly increased activity from 26 March through 14 April could have produced a substantially greater cloud. Such eruptive plumes frequently reach altitudes in excess of 5 km (*15*) and can form in a relatively short time. Examples include a 12-km cloud generated in about 2 minutes (*16*), a 20-km cloud in about 5 minutes, and a 30-km cloud in about 25 minutes (*17*).

Satellite photographs for 8 and 9 April were also examined for volcanic emissions (*18*). Because of extensive cloud cover south and east of Japan, no conclusions could be drawn from the photographs. If Kaitoku did, indeed, produce a plume around 9 April 1984, a crucial question is whether winds were favorable for transporting the plume to the observation site approximately 1470 km to the northeast. Since the mystery cloud was observed initially at an elevation of about 4300 m (*2*), wind analysis charts at the 700-millibar (~3000 m) and 500-mb (~5500 m) levels were examined for 8 and 9 April (*19*). Wind directions were not favorable, generally heading southeast across the northern part of the Philippine Sea through the Bonin, Volcano, and Mariana islands area and on into the western Pacific. Wind charts were available only at 12-hour intervals, but because of the consistency of wind patterns, any significant changes were unlikely during these 12-hour intervals.

Even if the negative evidence from the wind analysis is dismissed, other important questions have to be resolved. One is whether a volcanic plume transported to the site of the mystery cloud would have a spherical shape. Under the mechanism being considered, a powerful eruption over several hours would produce a cloud that is elongated horizontally. Therefore, if Kaitoku did produce the spherical mystery cloud, the eruption would have had to be of short duration, lasting 2 hours or less. The question then arises as to how such a cloud could have escaped detection at its source and throughout its path to the mystery cloud site. This, most likely, could have happened only if the eruption and transport occurred at night, since a cloud produced during daylight hours (assuming good visibility) could easily be observed from Iwo Jima, the nearest inhabited island (Iwo Jima, which has a maximum elevation of 169 m, is about 130 km south of Kaitoku). Pilots on the Tokyo-Anchorage route made their observations at about 1400 UT. For a 10-hour travel time (implying average wind velocities of at least 147 km/hour), this would suggest a time of origin for the cloud of about 0400 UT at Kaitoku. Sunset at Kaitoku would not have occurred until nearly 5 hours after the hypothetical eruption (*20*). Not only is Iwo Jima inhabited, but from 7 March through at least 10 May, the activity of this volcano was monitored by airplanes and helicopters of the Japan Maritime Safety Agency (JMSA), which has a base at Iwo Jima. They formally named this volcano "Kaitoku Seamount" and reported (*21*) that

> eruptive activity was at its highest level in mid- to late March when floating ejecta and vapor plumes were nearly always seen. Beginning in April, activity subsided gradually.

Their only notation for 8 or 9 April is that on 9 April the area of discolored water covered 0.3 by 5 km compared to the previously reported highest value of 13 by 30 km on 8 March. (JMSA's assessment of subsidence in activity beginning

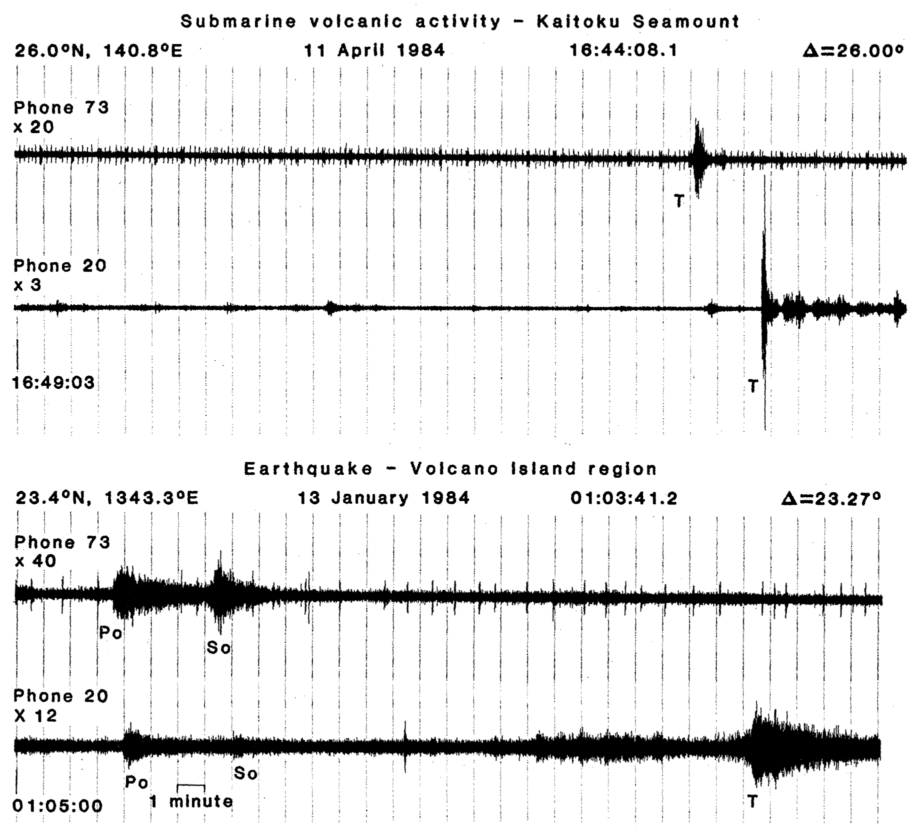
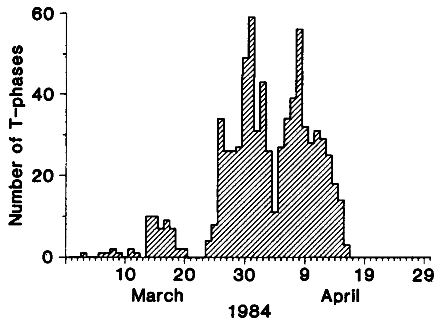



Fig. 3. One of the swarm-type Kaitoku T-phases from Fig. 2 shown in an expanded time scale. Also shown is an earthquake T-phase recorded on the same hydrophone. The earthquake-generated T-phase, unlike the swarm type T-phase, has associated ground arrivals [that is, Po/So phases (*8*)]. Phone 73 is one of the bottom phones (5.5-km depth) of the pentagonal array and phone 20 is a shallower phone suspended near the axis of the SOFAR channel (1-km depth). Relative gain levels are shown above the beginning of each trace. As indicated by these recordings, bottom phones are generally better receptors of ground phases, and SOFAR phones are generally better receptors of T-phases. Earthquake data were taken from the National Earthquake Information Service PDE listings. The depth and magnitude given for this earthquake are 33 km and 5.3 mb, respectively.



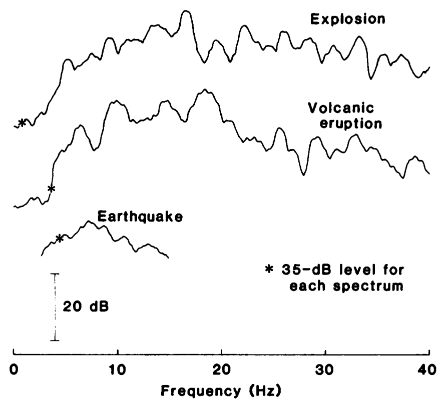




Fig. 4 (left). Estimated daily number of T-phases on the drum recordings (see Fig. 2) from 1 March through 30 April. Although numbers for 30 and 31 March are somewhat higher than the numbers for 7 and 8 April, it is apparent from Fig. 2 that T-phases observed on the later dates have substantially greater amplitudes. No recordings are available for 13 March because of a power outage. Fig. 5 (right). Spectra for the T-phases shown in Fig. 6. Only portions of each spectrum, where signal levels are at least 4 dB above the noise, are shown. System response has not been removed. A common level of 35 dB is indicated for each spectrum. Again, the similarities between the explosion and eruption spectra are evident.

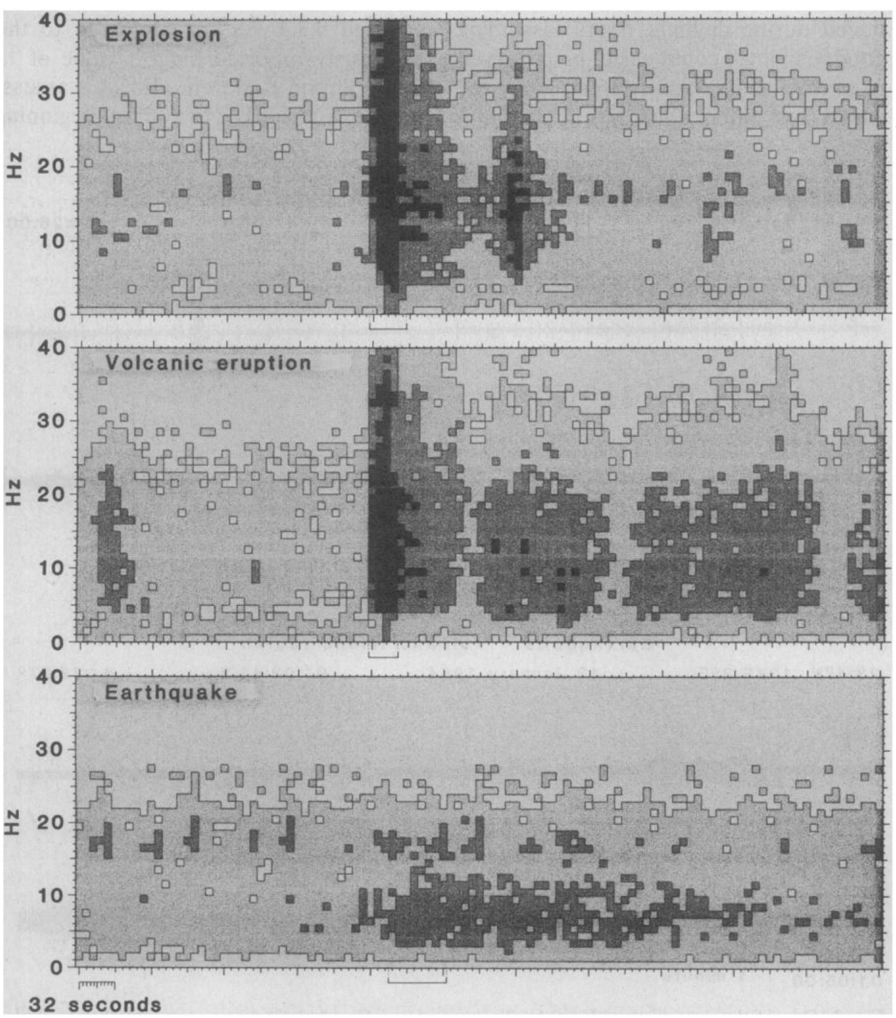



Fig. 6. Spectrograms for a T-phase produced by a man-made underwater explosion and for the eruption and earthquake T-phases shown in Fig. 3. All recordings are from phone 20. Time increases from left to right and frequency from bottom to top. Energy levels increase from light to dark with 12 decibels between shades. System response has not been removed. Brackets under each T-phase indicate the portion of the record from which the spectra shown in Fig. 5 were made. A comparison of the impulsive character and high-frequency content of these spectrograms shows that the spectrograms of the explosion and eruption are most closely related.

in April must have been based entirely on visual inspection rather than seismic monitoring, since 253 T-phases from the volcano were counted on the drum recordings at Wake during the last 15 days of March as compared with 444 during the first 15 days of April.)

Another question concerns the rise time of the mystery cloud. It emerged from a stratiform layer at about 4300 m and rose in about 2 minutes (*3*) to a maximum altitude of 18,000 m where growth continued until the cloud dissipated about 40 minutes after the initial sightings (*2*). If a plume from Kaitoku was transported 1470 km to the mystery cloud site, what was the mechanism for a vertical ascent of the volcanic materials at a rate of about 7 km/min? The only known natural phenomenon capable of producing such rapid and extensive vertical motions are volcanic eruptions at their source. The highest recorded updraft velocities for cumulonimbus clouds are in the range of 90 miles per hour (2.4 km/min) (*22*). Furthermore, to produce an apparent ascent rate of 7 km/min for the cloud top (as was observed for the mystery cloud), the actual updraft velocity required would be approximately 14 km/min (*23*).

In view of the foregoing analysis, the submarine eruption of Kaitoku Seamount and the sighting of the mystery cloud must be coincidental.

*Other Possible Explanations*. Remaining hypotheses include other volcanic eruptions and man-made explosions. No known active submarine volcano exists at the site of the mystery cloud. As demonstrated by the Kaitoku investigations, any submarine volcanism at 38.5°N, 146.0°E, would have been detected by the Wake hydrophones. No such activity was found. The only other reported eruptions that might be remotely considered occurred at Klyuchevevskaya Volcano (56.2°N, 160.8°E) in the Kamchatka Peninsula. Strombolian activity is reported only for 22 May, although the number of earthquakes increased from late March through May. No special mention is made of activity on 8 or 9 April (*24*). Klyucheveskaya Volcano is approximately 2250 km northeast of the mystery cloud site and winds were unfavorable (generally to the east-northeast) on 8 and 9 April at the 4300-m and 5500-m levels. No volcanism was reported for the Kurils; in Japan the long-term, well-monitored activity of Sakura-jima Volcano (31.6°N, 130.7°E; southwestern Japan, outside of the area shown in Fig. 1) continued throughout April with no reports of a large explosion on 8 or 9 April (*25*). Twenty-five explosions were observed at Sakura-jima during April—one on 8 April and one on 9 April. The largest explosions occurred on 12, 19, and 29 April. For January, February, and March 1984, the number of explosions reported are 22, 26, and 34, respectively. It is reasonable to assume that if the moderate or small explosions on 8 and 9 April produced the mystery cloud, then many other similar clouds produced by even larger eruptions of Sakura-jima should have been sighted. The current eruptive phase of Sakura-jima began in 1955 (*26*). Suwanose-shima Volcano in the Ryukyu Islands (29.5°N, 129.7°E) (not shown in Fig. 1) has been active since November 1982, but nothing unusual was reported at this location for 8 and 9 April (*27*). As with Sakura-jima, if Suwanose-shima produced the 9 April mystery cloud, other similar clouds should have been sighted.

*Conclusions*. Wake Island hydrophone recordings were searched for possible explanations of the mystery cloud observed at 38.5°N, 146.0°E, by flight crews of commercial airlines. No evidence is found for a single large underwater explosion from this or other locations at the time of the sightings or in the hours preceding those sightings. Instead, the most conspicuous feature of the recordings is a swarm of impulsive T-phases that began in March 1984 and intensified to a maximum around 8 or 9 April, just before and during the sightings of the mystery cloud. The source of this activity was estimated to be in the Volcano Islands (south of Japan), and this estimate was confirmed by sightings of active submarine volcanism by the JMSA, which formally named the volcano Kaitoku Seamount. Because of Kaitoku's remoteness and the intensity of activity on 8 and 9 April, it seemed possible that during the nighttime hours favorable winds could have transported a volcanic plume northward approximately 1470 km over the Pacific to the mystery cloud site. Analyses of wind directions at 4300- and 5500-m levels, however, revealed that materials at these elevations over Kaitoku would be transported not to the north but to the east or southeast. Furthermore, even if favorable winds had been found, no natural mechanism could produce the observed rise time of the cloud at 38.5°N, 146.0°E (from about 4300 m to 18,000 m in approximately 2 minutes)—with the possible exception of another volcanic eruption at that site. Submarine volcanism at 38.5°N, 146.0°E, would have been recorded by the Wake hydrophones. No such activity was found. It is unlikely that any other volcanic eruptions could have produced the mystery cloud.

Therefore, on the basis of data available at this time, our analyses indicate that the mystery cloud was produced either by an as yet unknown natural phenomenon or by a man-made atmospheric explosion.

### References and Notes


1. Transcription from Japan Airlines flight 036 to Anchorage International Flight Service on 9 April 1984, at 1406 Greenwich mean time, Federal Aviation Administration (FAA)–Alaska Region.
2. Report of interviews taken by Jim Derry, Special Agent, FAA-Alaska Region, with C. H. McDade, Captain, Japan Air Lines flight 036; Cornelis Vander Berg, Captain, KLM Royal Dutch Airlines flight 868; Reint Sol, First officer, KLM Royal Dutch Airlines flight 868; and Mike Howe, Captain, Flying Tiger Lines flight 078.
3. Anchorage *Daily News*, 10 April 1984, p. A-1.
4. *Ibid.*, 12 April 1984, p. A-1.
5. Honolulu *Advertiser*, 10 April 1984, p. B-1; *Newsweek*, 30 April 1984, p. 25.
6. *SEAN Bulletin* **9-4**, 8 (1984).
7. The value 1.48 km/sec was taken from R. Johnson and R. Norris [*J. Geophys. Res.* **73**, 4695 (1968)].
8. For a recent discussion of Po/So phases, see D. Walker [*Eos* **65**, 2 (1984)].
9. This explosion T-phase was one in a sequence of 11 observed between 0307 and 0518 hours on 9 April 1984. Four occurred at intervals of 5 minutes, three were observed later at 5-minute intervals, and the rest were recorded at random intervals. All of these phases were similar in their appearance and offset times on the differing hydrophones. Some variations in amplitude were observed. Estimated source locations are at an azimuth to the array approximately 50° north of west. Solutions within a 2-second contour begin along this azimuth at a range of about 300 km and extend to the antipode of the array. Included among the many source locations is the observed site of the mystery cloud. These explosions occurred 9 to 11 hours before the first sighting of the mystery cloud. Had a cloud been produced at those times (local midafternoon) at the mystery cloud site, it seems likely that it would have been observed before the sightings at 1400 UT. Similar experiments in the northwestern Pacific are often recorded by the Wake hydrophone array.
10. R. Norris and R. Johnson, *J. Geophys. Res.* **74**, 650 (1969).
11. R. Norris and D. Hart, *ibid.* **75**, 2144 (1970); R. Johnson and R. Norris, *ibid.* **77**, 4461 (1972).
12. For the Myojin volcano, see R. Morimoto [*Bull. Volcanol.* **2-23**, 151 (1960)]; for Tori-shima, see (*10*); and for Farallon de Pajaros, see H. Kuno [*Catalogue of the Active Volcanoes of the World Including Solfatara Fields*, part 11, *Japan, Taiwan, and Marianas* (International Association of Volcanology, Rome, 1962)].
13. T. Simkin *et al.*, *Volcanoes of the World* (Hutchinson Ross, Stroudsburg, Pa., 1981).
14. *SEAN Bulletin* **9-2**, 3 (1984).
15. G. Macdonald, *Volcanoes* (Prentice-Hall, Englewood Cliffs, N.J., 1972).
16. ———, *ibid.*, p. 328.
17. S. Thorarinsson, in *The Eruption of Hekla 1947–1948*, T. Einarsson, G. Kjartansson, S. Thorarinsson, Eds. (Visindafelag Islendinga, 1954), p. 2.
18. Infrared photographs taken at 3-hour intervals from Geostationary Meteorological Satellite 1. Space shuttle photography was also examined by C. A. Wood of the Lyndon B. Johnson Space Center, but no pictures were available for the northwestern Pacific.
19. The 500-mb and 700-mb wind charts for the northern hemisphere were provided by the National Climatic Data Center.
20. *The Astronomical Almanac for the Year 1984* (Government Printing Office, Washington, D.C., 1983).
21. *SEAN Bulletin* **9-5**, 6 (1984).
22. T. A. Schroeder, personal communication. He is assistant professor of Meteorology, University of Hawaii at Manoa, and former chairman of the American Meteorological Society's committee on severe local storms.
23. H. R. Byers and R. R. Braham, Jr., *The Thunderstorm* (Government Printing Office, Washington, D.C., 1948).
24. *SEAN Bulletin* **9-5**, 4 (1984).
25. *Ibid.*, p. 5.
26. *Ibid.* **9-3**, 24 (1984).
27. *Ibid.*, p. 25.


28. This research was sponsored by the Physical and Geophysical Sciences Directorate of the Air Force Office of Scientific Research under contract F49620-84-C-0003 and by the U.S. Arms Control and Disarmament Agency. We thank P. Steucke, Public Affairs Officer of the Federal Aviation Administration's Alaska Region, for providing transcripts and reports of interviews; T. Schroeder and J. Sadler for helpful comments and discussions on meterological topics; G. P. L. Walker for discussions of volcanism; and A. Chang for bringing the mystery to our attention. We thank E. Berg and M. Garcia for reviewing this article and R. Pujalet for editorial assistance. This is Hawaii Institute of Geophysics Contribution No. 1564.

23 October 1984; accepted 30 November 1984