Reports

Mercury Content of *Equisetum* Plants Around Mount St. Helens One Year After the Major Eruption

Abstract. *The mercury content of young* Equisetum *plants collected around Mount St. Helens was higher in the direction of Yakima and Toppenish, Washington (northeast to east-northeast), than at any other compass heading and was about 20 times that measured around Portland, Oregon. The increase in substratum mercury was not as pronounced as that in plants but was also higher toward the northeast, the direction taken by the May 1980 volcanic plume.*

The injection of volcanic material into the atmosphere by Mount St. Helens began on 27 March 1980 and continued, with quiescent interludes, for several months (*1*).

On 18 May 1980, a major eruption and explosion devastated some 500 km^2 of timberland north of the mountain (*2*). The blast zone, as delimited by the interface between singed and green standing timber, extended no more than 20 km to the east and northeast of the mountain (*2*), whereas the massive volcanic plume covered a far greater area; the lower portions of the plume moved in an easterly direction at jet stream velocities (*3*).

The chemistry of the 18 May plume has been examined (*4*), but mercury was not among the trace elements studied even though its significance as a primary volcanic effluent has been well established (*5*, *6*). The accumulation and release of mercury by plants have also been the subject of study (*7*), and it has been proposed that vegetation has a major role in the distribution and cycling of volcanic mercury (*8*). Because of their ability to accumulate mercury, plants may be of value as geothermal indicators.

To test this, a study of plant mercury content was conducted around Mount St. Helens in June 1981, 1 year after the major eruption. Plants and soil were collected between 18 and 20 June from about 30 to 140 km, line-of-sight distances, around the volcano, beginning and ending in Portland, Oregon.

The indicator plant *Equisetum arvense*, the common horsetail, was selected because it was available in quantity at every site, and because comparative data for the period 1969 to 1975 in the Pacific Northwest were available. Substratum samples were collected at the same sites as plants.

All samples were sealed in 10-mil polyethylene bags and stored in the cold until analyzed. Triplicate samples (10 to 15 g, wet weight) were digested in nitric and sulfuric acid mixtures and analyzed by flameless atomic absorption (*6*, *9*). To prevent loss by volatilization, samples for mercury analysis were not dried, and other portions of the plant and soil samples were used to determine dry weights.

More than 350 species in plants and animals have been analyzed for mercury in our laboratory since 1968; among them are several members of the genus *Equisetum* including *E. arvense* from the Pacific Northwest (Table 1). The tests show *E. arvense* to be a relatively poor accumulator of mercury under ordinary (geothermally inactive) conditions. A low concentration of mercury was found in soil and plant samples from Portland during the collection period, but at all other sites around the volcano both plant and soil mercury concentrations were elevated (Fig. 1 and Table 2). High concentrations were most striking in the plant samples from Yakima and Toppenish, Washington, and in the substratum at Toppenish, which appeared to be particularly high in ash. Among our substratum samples, visibly high accumulations of ash were also found at Toutle River, Washington, and in Yakima. Analyses showed mercury concentrations of 10.2 and 9.1 parts per billion (ppb), respectively. This agrees well with reported mercury concentrations of 8 to 13 ppb in ashfall collected in May 1980 at Tieton, Washington, 98 km from the mountain, to Missoula, Montana, some 644 km distant (*10*). It appears that ash mercury is not highly mobile. Thus the samples from the east-northeast to east of Mount St. Helens, the major stratospheric plume direction of the 18 May 1980 eruption, were elevated by an order of magnitude or more in mercury content relative to previous and current samples from Portland and samples collected at earlier times from various Pacific Northwest locations.

The values reported here for mercury content of soil, ash, and *Equisetum* are quite low when compared with general

Table 1. Mercury content of samples of Pacific Northwest *Equisetum arvense* collected between 1969 and 1975. Values are mean ± 1 standard deviation (three to six samples, 10 to 15 g).

Location	Collection date	Mercury (ppb, dry)
Banff, Alberta	June 1969	1.8 ± 1.1
Seattle, Washington	June 1969	2.3 ± 0.8
	July 1972	1.6 ± 0.7
Juneau, Alaska	July 1972	1.0 ± 0.6
Portland, Oregon	December 1972	2.4 ± 1.6
	March 1975	1.9 ± 0.9

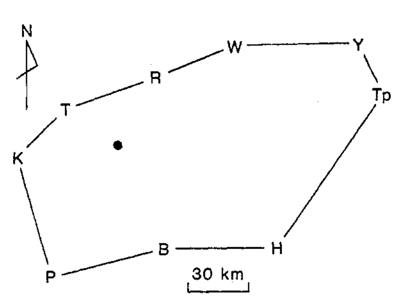

Fig. 1. Schematic map of Mount St. Helens (solid circle) and environs showing sample collection stations in Oregon at Portland (*P*) and in Washington at Kelso (*K*), Toutle River (*T*), Randle (*R*), White Pass (*W*), Yakima (*Y*), Toppenish (*Tp*), Horsethief Lake (*H*), and Bonneville (*B*).

Table 2. Mercury content of *Equisetum arvense* and associated substratum around Mount St. Helens, June 1981. Values are mean ± 1 standard deviation (three to six samples, 10 to 15 g).

Location	Mercury (ppb, dry)	
	Substratum	*Equisetum*
Portland	1.4 ± 0.2	2.2 ± 1.2
Kelso	15.0 ± 1.9	6.2 ± 0.2
Toutle River	10.2 ± 0.2	9.4 ± 0.8
Randle	5.3 ± 0.5	7.5 ± 0.9
White Pass	5.7 ± 0.5	7.0 ± 0.7
Yakima	9.1 ± 0.9	22.6 ± 2.8
Toppenish	23.2 ± 3.9	45.1 ± 4.0
Horsethief Lake	15.6 ± 0.8	9.5 ± 0.5
Bonneville	17.1 ± 1.5	15.8 ± 0.8

plant and soil data from continuously active volcanic locations such as Iceland and Hawaii (*7*). More common values in both of these locations would be one or two orders of magnitude higher.

In general, mercury content of plants is high when mercury content of the soils is also high, but this relation does not always hold. The mercury content of the substratum in both the Kelso and Horsethief Lake regions of Washington, for example, is about 15 ppb, but the mercury content of the plants at Kelso is about 6 ppb and that at Horsethief Lake is about 9 ppb. In some instances, such as at Kelso, the mercury content of plants is less than that of the substrate; in other places, such as at Yakima and Toppenish, the plants contain higher concentrations than the substrate. The variations probably arise from differences in the relative availability to the plant of mercury in the substratum and in the plume ash.

The plants we sampled were, on the average, 10 cm or less in height and less than 6 months in age, yet they reflected with reasonable accuracy the direction of a volcanic plume generated during an eruption that took place months before these plants began their growth.

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References and Notes

1. J. B. Pollack, *Science* **211**, 815 (1981).
2. S. Kieffer, *Nature (London)* **291**, 568 (1981).
3. E. Danielsen, *Science* **211**, 819 (1981).
4. E. Inn, J. Vedder, E. Condon, D. O'Hara, *ibid.*, p. 821; T. Vossler, D. Anderson, N. Aras, J. Phelan, W. Zoller, *ibid.*, p. 827.
5. A. Andren and J. Nriagu, *The Global Cycle of Mercury*, J. Nriagu, Ed. (Elsevier/North-Holland, Amsterdam, 1979); J. Connor, *Sci. Total Environ.* **12**, 241 (1979); B. W. Gandrud and A. L. Lazrus, *Science* **211**, 826 (1981); A. Eshleman, S. Siegel, B. Siegel, *Nature (London)* **233**, O. Joensuu, *Science* **172**, 1027 (1971); J. McCarthy, J. Meuschke, W. Ficklin, R. Learned, *U.S. Geol. Surv. Prof. Pap. 713* (1973), p. 37; B. Siegel and S. Siegel, *Nature (London)* **241**, 526 (1973); S. Siegel and B. Siegel, *Environ. Sci. Technol.* **9**, 473 (1975).
6. B. Siegel and S. Siegel, *Environ. Sci. Technol.* **12**, 1036 (1978); *Geothermal Res. Counc. Trans.* **2**, 596 (1978).
7. J. Barber, W. Beauford, Y. Sheih, *Mercury, Mercurials and Mercaptans*, M. Miller and T. Clarkson, Eds. (Thomas, Springfield, Ill., 1973); D. Ben-Bassat and A. Mayer, *Physiol. Plant.* **38**, 128 (1975); *ibid.* **40**, 157 (1977); *ibid.* **42**, 32 (1978); J. Garty, M. Galun, E. Kessel, *New Phytol.* **82**, 159 (1979); W. Kama and S. Siegel, *Org. Geochem.* **2**, 99 (1980); G. McMurtry, R. Brill, B. Siegel, S. Siegel, *Antarct. J. U.S.* **14**, 206 (1979); B. Siegel and S. Siegel, *Water Air Soil Pollut.* **5**, 335 (1976); in *Biogeochemistry of Mercury in the Environment*, J. Nriagu, Ed. (Elsevier/North-Holland, Amsterdam, 1979), pp. 131–159; S. Siegel and B. Siegel, in *Third Scientific Assembly, International Association of Meteorology and Atmospheric Physics*, Hamburg, West Germany, 17 to 28 August 1981, Abstr. 3.7; S. Siegel, J. Okasako, P. Kaalakea, B. Siegel, *Organ. Geochem.* **2**, 139 (1980); S. Siegel, N. Puerner, T. Speitel, *Physiol. Plant.* **32**, 174 (1974); S. Siegel, B. Siegel, A. Eshleman, K. Bachmann, *Environ. Biol. Med.* **2**, 81 (1973); S. Siegel, B. Siegel, G. McMurtry, *Water Air Soil Pollut.* **13**, 109 (1980); S. Siegel, B. Siegel, J. Okasako, *ibid.* **15**, 371 (1981); S. Siegel, B. Siegel, N. Puerner, T. Speitel, F. Thorarinsson, *ibid.* **4**, 9 (1975).
8. B. Siegel and S. Siegel, paper presented at Botanical Society of America symposium, "Biological Effects of Mount St. Helens Eruption," held at the 62nd annual meeting, AAAS Pacific Division, Eugene, Ore., 14–19 June 1981.
9. S. Siegel and B. Siegel, *Water Air Soil Pollut.* **9**, 113 (1978).
10. J. S. Fruchter *et al.*, *Science* **209**, 1116 (1980).
11. We thank D. N. Siegel, University of Oregon, for his able assistance in the field.

20 October 1981; revised 12 January 1982

Comet Encke: Radar Detection of Nucleus

Abstract. *The nucleus of the periodic comet Encke was detected in November 1980 with the Arecibo Observatory's radar system (wavelength, 12.6 centimeters). The echoes in the one sense of circular polarization received imply a radar cross section of 1.1 ± 0.7 square kilometers. The estimated bandwidth of these echoes combined with an estimate of the rotation vector of Encke yields a radius for the nucleus of* $1.5^{+2.3}_{-1.0}$ *kilometers. The uncertainties given are dependent primarily on the range of models considered for the comet and for the manner in which its nucleus backscatters radio waves. Should this range prove inadequate, the true value of the radius of the nucleus might lie outside the limits given.*

Comets are widely believed to represent samples of the most primitive material of the solar nebula (*1*), and their nuclei especially have been the subject of intense study. However, direct study of the nucleus of a comet has been hindered by the difficulty in separating the light reflected by the nucleus from that scattered by the surrounding coma. Apart from a spacecraft mission to a comet, ground-based radar appears to be the only technique available for the direct detection of a nucleus. But such detection is rarely possible because of the combination of the small size of a comet's nucleus and its generally great distance from the earth.

Comet Encke has the shortest orbital period of any known comet (P_o = 3.3 years), and has been observed carefully during most of its passages through perihelion since its discovery in 1786. Its orbit has been determined accurately (*2*), and its nucleus described (*3*) as an inho-

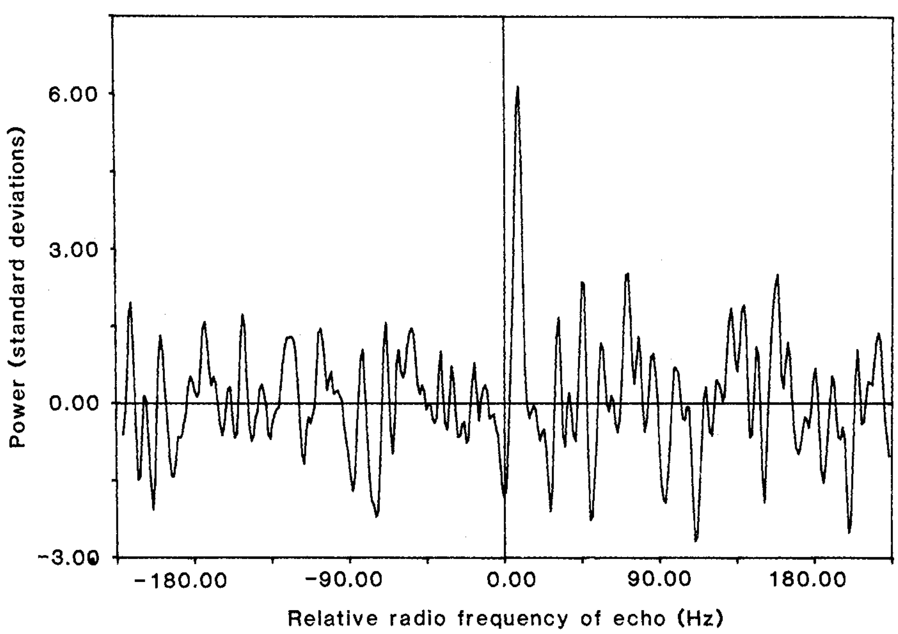

Fig. 1. Smoothed spectrum from radar observations of comet Encke made during the period 2 to 8 November 1980. The abscissa represents the radio frequency of the received signal relative to the frequency calculated from the ephemeris for the comet; the scale spans an interval slightly larger than the smallest difference between any two of the four transmitted frequencies (*4*). The central peak of the echo is offset by about 7.5 Hz from the ephemeris value which corresponds to the origin of the abscissa. The ordinate represents echo power in units of the root-mean-square fluctuations of the noise power. The distribution of the noise samples in the final spectrum approximates to the expected degree a Gaussian probability distribution of mean zero and standard deviation unity.