References and Notes

1. P. V. Hobbs, L. F. Radke, J. L. Stith, *Science* **195**, 871 (1977).
2. R. D. Cadle, *The Measurement of Airborne Particles* (Wiley-Interscience, New York, 1975), p. 111.
3. W. E. Ranz and J. B. Wong, *Ind. Eng. Chem.* **44**, 1371 (1952).
4. M. J. Pilat, D. S. Ensor, J. C. Bosch, *Atmos. Environ.* **4**, 671 (1970).
5. E. R. Frank and J. P. Lodge, Jr., *J. Microsc. (Paris)* **6**, 449 (1967).
6. *Air Quality Criteria for Sulfur Oxides* (U.S. Department of Health, Education, and Welfare. Public Health Service, Washington, D.C., 1969).
7. The National Center for Atmospheric Research is sponsored by the National Science Foundation.

25 March 1977; revised 27 June 1977

The data of Cadle and Mroz (*1*), based on observations of St. Augustine volcano on 1 February 1976, provide an interesting comparison with the observations of Hobbs *et al.* (*2*) made between 8 and 18 February 1976. We believe that these two sets of observations are not in conflict, and that the differences were due to changes in the state of the volcano.

The first series of explosive eruptions (23 to 26 January 1976) removed much of the dome that formed during the 1964 eruption. These eruptions were followed by a relatively quiet period (during which Cadle and Mroz obtained their measurements). The next series of explosive eruptions (during which we made our measurements) began on 6 February, and intermittent violent eruptions continued until 13 February. This second series of eruptions produced a number of spectacular nuées ardentes (*2*, *3*). A new dome began to rise from the crater on 11 February. This activity and the accompanying seismic signals (*4*) were probably the result of magmatic movement rather than the result of the intrusion of groundwater as suggested by Cadle and Mroz (*1*).

We began making our measurements during what may have been the early stages of a dome-building sequence. It appears that at this stage the volcano was emitting much less sulfur than during either the first series of explosive eruptions or the quiet period that followed. Ash samples collected at nearby Homer, Alaska, from the first series of explosive eruptions were richer in sulfur than the ash samples we obtained from the second series of eruptions.

In (*2*) we reported on some of the characteristics of the brown clouds produced by the explosive eruptions and the more continuous white emissions. Although the white emissions often resembled water clouds, in fact they consisted mainly of ash. The particles > 0.1 μm in diameter in the white emissions had an elemental composition and a morphology similar to those of the ash particles in the brown clouds. The different appearances of these two emissions were evidently due primarily to different particle size distributions (*2*). The brown clouds also had significantly lower concentrations of gaseous sulfur (0.07 mg m^{-3}) than the white emissions (0.2 to 3 mg m^{-3}). The white emissions that we studied generally contained no liquid water, were water-subsaturated, and did not evaporate (Fig. 1a).

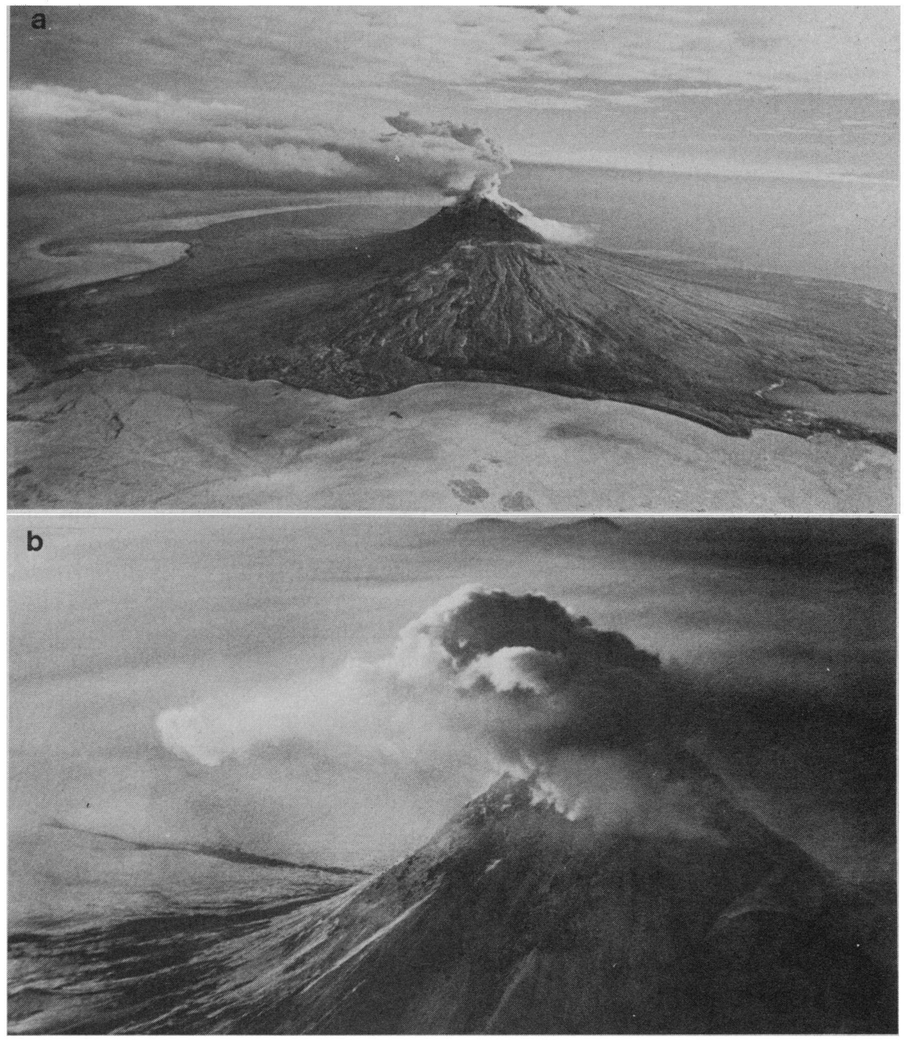

Fig. 1. (a) St. Augustine volcano on 18 February 1976. The white emissions discussed by Hobbs *et al.* (*2*) are those on the left. (b) St. Augustine volcano on 1 February 1976, illustrating the type of white cloud sampled by Cadle and Mroz. [Photos by E. Patterson, National Center for Atmospheric Research, Boulder, Colorado]

The white clouds discussed by Cadle and Mroz (Fig. 1b) are quite different from the white emissions discussed in (*2*). The white clouds sampled by Cadle and Mroz (Fig. 1b) evaporated sharply within a short distance from the mountain (note the similarity of the white cloud in Fig. 1b to the small white cloud on the right of Fig. 1a, which is quite distinct from the main white emissions to the left in Fig. 1a). It appears that the white clouds sampled by Cadle and Mroz contained much more liquid water, less ash, and higher gaseous sulfur concentrations than the white emissions we studied. Apparently, from the observations reported in (*1*), such clouds also contain high concentrations of acid sulfate aerosol. Measurements obtained by us on 22 April 1977 at St. Augustine (a year after any major eruptions), in emissions similar in appearance to those in which Cadle and Mroz obtained their measurements, also revealed little ash and primarily acid sulfates for aerosol > 0.1 μm. In contrast, our earlier (February 1976) studies of the white emissions showed no evidence of acid sulfates in particles > 0.1 μm; however, the enhanced concentrations of particles < 0.1 μm in these emissions (*2*) may have been due to sulfates produced by gas-to-particle conversion.

PETER V. HOBBS
LAWRENCE F. RADKE
JEFFREY L. STITH
Atmospheric Sciences Department, University of Washington, Seattle 98195

References and Notes

1. R. D. Cadle and E. J. Mroz, *Science* **199**, 455 (1978).
2. P. V. Hobbs, L. F. Radke, J. L. Stith, *ibid.* **195**, 871 (1977).
3. J. L. Stith, P. V. Hobbs, L. F. Radke, *Geophys. Res. Lett.* **4**, 259 (1977).
4. J. Kienle and R. B. Forbes, "Augustine—evolution of a volcano" (Annual Report, Geophysical Institute, University of Alaska, Fairbanks, 1976).
5. Research supported by NSF grants ATM-74-14726-A02 (Atmospheric Research Section, Meteorology Branch) and EAR76-15392 (Earth Sciences Section, Geochemistry).

8 November 1977

Vision in Cubomedusan Jellyfishes

The report by Wald and Rayport (*1*) on visual physiology in alciopids complements the recent ultrastructural study (*2*) of the remarkable eyes of these worms. However, adding annelids to molluscs, arthropods, and vertebrates does not complete the list of animals with elaborate eyes (*3*). One outstanding example is found in the cubomedusan jellyfishes (*4*) of tropical marine waters, the eyes of which were described by the end of the last century (*5, 6*).

Cubomedusans have as many as 24 eyes located near the bell margin, and the most complex of these eyes have an epidermal cornea, spheroidal cellular lens, and upright retina (Fig. 1). The retina is composed of layers, corresponding to those of alciopids: a presumably sensory layer, a pigmented layer, a nuclear layer, and a region of nerve fibers. The cells described by Berger (*6*) as sensory contain a zone of pigment granules at the level of the pigmented layer and, in the sensory layer, long "axial fibers" which he tentatively identified as cilia and clearly illustrated with basal bodies. There are roughly 11,000 sensory cells in the eye (*7*), a number comparable to that estimated for alciopids (*1*). Elongate pigment-filled cells (supportive cells?) extend between the sensory cells in sections from animals fixed in the light, and are partially withdrawn in sections from animals fixed in the dark; Berger interpreted these observations as evidence for a kind of adaptation to light and dark, similar to that in arthropodan and other complex eyes. Between the lens and the retina is a "capsule" through which narrow processes extend from the tips of the long pigment cells to the cells of the lens, features which Berger (*6*) speculated might be involved in accommodation for near and far vision.

Like alciopids, cubomedusans have been studied little (*8, 9*). They are agile and rapid swimmers; specimens only about 3 cm high have been clocked at up to 6 m per minute (*10*). They are active both by day and by night, and in the dark exhibit strong positive phototaxis (*9, 10*); they will orient accurately to the light of a match as much as 1.5 m away even if the match is extinguished before orientation is completed (*9*). Their combination of speed and fine directional sensitivity to light might enable them to orient to luminescent prey at night. Larson (*10*) observed that cubomedusans attracted to a night-light "neither swam toward prey nor avoided obstacles," but the interesting possibility of image-forming vision under more normal conditions remains. Cubomedusans are unique among cnidarians in engaging in copulation (*11*); might the eyes be somehow involved in this behavior?

Cubomedusan eyes are so similar to the camera eyes of vertebrates and cephalopods that it would be surprising if studies of them, on the level now begun for alciopids (*1, 2*), did not yield valuable perspective and reveal some more elaborate functions than ordinary directional sensitivity.

JOHN S. PEARSE
VICKI B. PEARSE
Center for Coastal Marine Studies,
University of California,
Santa Cruz 95064

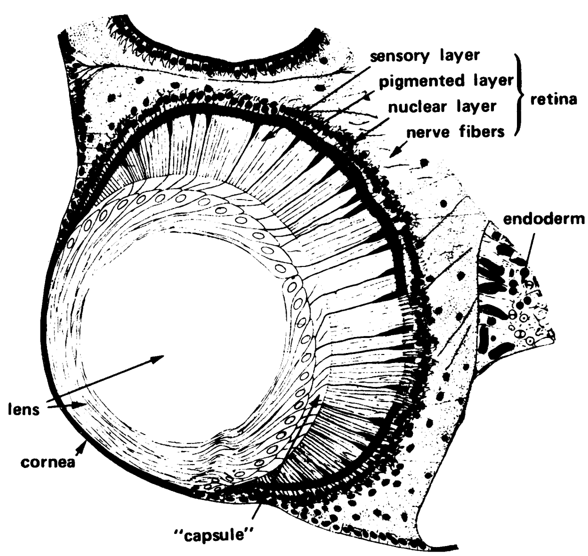

Fig. 1. Section of cubomedusan eye, from Berger (*6*, figure 7); relabeled. Part of the pigmented zone is drawn without pigment to reveal the basal bodies of the "axial fibers" that extend distally through the sensory layer. Berger states that in small specimens, the lens is cellular throughout; in larger adults, the central region often shows less distinct cellular features or even appears homogeneous, as drawn here.

References and Notes

1. G. Wald and S. Rayport, *Science* **196**, 1434 (1977).
2. C. O. Hermans and R. M. Eakin, *Z. Morphol. Tiere* **79**, 245 (1974).
3. Elaborate lensed eyes, organized on the scale of organelles, are found even among dinoflagellates (protistans); see C. Greuet, *Protistologica* **4**, 209 (1968). See also review by R. M. Eakin, in *Handbook of Sensory Physiology*, H. J. A. Dartnall, Ed. (Springer, Berlin, 1972), vol. 7, No. 1, pp. 625–684.
4. Cubomedusans are usually placed in the class Scyphozoa, phylum Cnidaria. It has been argued that they constitute a separate cnidarian class, the Cubozoa; see B. Werner, *Helgol. Wiss. Meeresunters.* **27**, 461 (1975).
5. C. Claus, *Arb. Zool. Inst. Wien* **2**, 221 (1878); W. Schewiakoff, *Morphol. Jahrb.* **15** (No. 1), 21 (1889); F. S. Conant, *Mem. Biol. Lab. Johns Hopkins Univ.* **4** (No. 1), 1 (1898); see also L. H. Hyman, *The Invertebrates* (McGraw-Hill, New York, 1940), vol. 1, pp. 511–515.
6. E. W. Berger, *Mem. Biol. Lab. Johns Hopkins Univ.* **4** (No. 4), 1 (1900).
7. We arrived at this estimate by counting the sensory cells in figure 1 (cross section) of Berger (*6*); we then calculated the average density (3.3×10^5 cell/mm^2) and estimated the retinal area, assuming that the retina occupies half of a spherical eye 145 μm in diameter (measured inside pigment layer on figure 7 of Berger; see our Fig. 1).
8. Cubomedusans are notorious, however, for their painful, somtimes deadly sting, and they are commonly known as "sea wasps"; studies have centered on their effects on bathers [for example, see Barnes (*9*)].
9. J. H. Barnes, in *The Cnidaria and their Evolution*, W. J. Rees, Ed. (Academic Press, New York, 1966), p. 307.
10. R. J. Larson, in *Coelenterate Ecology and Behavior*, G. O. Mackie, Ed. (Plenum, New York, 1976), p. 237.
11. B. Werner, *Mar. Biol.* **18**, 212 (1973).

13 July 1977; revised 11 November 1977

Particles in the Eruption Cloud from St. Augustine Volcano

PETER V. HOBBS, LAWRENCE F. RADKE and JEFFREY L. STITH

Science **199** (4327), 457-458.
DOI: 10.1126/science.199.4327.457