A future option that is being actively planned is to add 16 more quadrupole magnets. But space around the ring is so tight this is barely feasible, especially since the area near the dipole bending magnets must be left free to capture the synchrotron radiation. Duke notes that the use of superconducting quadrupoles would help in this regard. These would be smaller and thus take up less space than conventional electromagnets. Although no particular "high brightness" option has been approved for the laboratory, Duke adds that the liquid helium refrigerator for the superconducting wiggler was deliberately chosen to be large enough to serve several more magnets.

The combination of 16 more quadrupoles of some type with the higher beam current permitted by use of the DESY klystron design would raise the SRS's brightness by more than a factor of 10 and would put it in Brookhaven's class. This is a future development, however. For the present, Munro hopefully argues, what one does with available facilities matters just as much as their intrinsic capabilities. Some of the traditional (if a field of research this young can have traditions) areas of investigation are already passé, and it is critical to be ready to open new ones. Among several possibilities, Munro has considerable enthusiasm for time-resolved spectroscopy, a technique for following the changes in the spectrums of rapidly changing specimens. This kind of investigation is possible because the circulating electron beam actually consists of discrete "bunches" of particles, each of which emits a pulse of radiation as it passes a port. With a high (500 megahertz) r-f frequency, the SRS has quite a short bunch length and hence emits a rapid pulse of light with a pause before the next pulse. The duration of the pause depends on the number of bunches. The SRS operates most easily with 160, which gives too short a pause for time-resolved spectroscopy, but a single bunch mode of operation is also possible, and the SRS operators are learning how to run this way.

—ARTHUR L. ROBINSON

Domesday Book of the World's Volcanoes

The newest compilation of volcanic eruptions runs the gamut from smallest to largest, and warns that the worst may be yet to come

Scientists in many fields may find *Volcanoes of the World** as fascinating reading as any best-selling novel. Its characters are the 1343 volcanoes of the world, its action the 5564 known eruptions of the past 10,000 years. It has violence, death, and destruction on a mind-boggling scale. The plot is rather thin, but the heart of the book, 200 pages of computer printout prepared at the Smithsonian Institution's National Museum of Natural History, makes up for that. It provides easy access to perhaps the most complete record of volcano behavior available.

Its possible uses are numerous. A biologist might ask which eruptions have formed new islands, ideal places to study plant and animal colonization. Details of all 96 island-forming eruptions are there. An anthropologist could ask how often the cultures of coastal Papua New Guinea have been disrupted by volcanic activity. During this century alone, the 11 volcanoes just off New Guinea's north coast produced 66 eruptions. A geologist could ask which volcanoes in historic times formed lava domes like those of Mount St. Helens. There are 86 such volcanoes, which have had 217 known dome-forming eruptions. Kamchatka's Bezymianny alone, whose initial eruptive behavior closely resembled that of Mount St. Helens, has had 15 dome-forming eruptions since 1955. A researcher can extract this information and more from this latest compilation of the history of volcanism by consulting the three separate listings of eruptions arranged by region, by volcano name, and by date. A bibliography of 709 references can lead to additional details.

Volcanoes of the World is also something of a *Guinness Book of World Records*. It includes the highest volcano having eruptions in the historic record (Llullaillaco, at 6723 meters in the Chilean Andes), as well as the briefest major eruption on record (the draining of a 20-million-cubic-meter lava lake in Zaire in less than an hour). The smallest eruption included in this volume occurred at Krafla in Iceland. In 1977, startled researchers watched 1.2 cubic meters of lava spurt out of a borehole that they had drilled as part of a geothermal study.

Which eruption was the biggest in history depends on what is meant by bigness. If the volume of erupted lava is the gauge, Iceland also has the record for the largest historic eruption—12.3 cubic kilometers of lava flowed from Lakagígar in 1783. If brute power counts, then perhaps the A.D. 186 eruption of New Zealand's Taupo is the winner. It lofted 80 percent of all of its ash, or 20 cubic kilometers, to a distance of more than 220 kilometers, according to George Walker of the University of Hawaii. Lacking a Richter-type scale for volcanic eruptions, the compilers of *Volcanoes* have included values of a volcanic explosivity index (VEI) developed by Christopher Newhall of the U.S. Geological Survey in Vancouver, Washington, and Stephen Self of Arizona State University. They combined eight measures of eruption size—including the volume of ejecta, eruption column height, duration, and degree of stratospheric injection—into a scale ranging from 0, nonexplosive, to 8, more explosive than any known eruption of the past 10,000 years. Only one event, the 1815 eruption of Tambora, received a VEI of 7, but 16 received indexes of 6. The eruption of Mount St. Helens on 18 May 1980 rated a 5, or "very large," but just barely.

As replete with information as *Volcanoes of the World* is, its authors warn that it, and all other such compilations, are in one respect seriously flawed. Even in recent decades, they say, significant eruptions have probably gone unrecorded because of haphazard reporting. If true, that would cause real problems for those searching the record for cycles of alternating high and low volcanic activity. Such cycles have been identified by some researchers and connected with changes in global climate. The likelihood that an eruption would be both observed

*Tom Simkin, Lee Siebert, Lindsay McClelland, David Bridge, Christopher Newhall, and John Latter, *Volcanoes of the World*: A Regional Directory, Gazetteer, and Chronology of Volcanism During the Last 10,000 Years (Hutchinson Ross Publishing Co., Stroudsburg, Pa., August 1981). Available from Academic Press, 111 Fifth Avenue, New York 10003. $19.75.

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and recorded in the scientific literature increased sharply around 1500 and again around 1800, Tom Simkin of the National Museum of Natural History points out. These improvements were probably in response to exploration, colonization, and advances in communication. "Even in the past 120 years, however, we find historical trends in reporting overshadowing any real trends in volcanism," Simkin and his coauthors warn.

The more attention the world pays to volcanic eruptions, the authors reason, the larger the number of eruptions that will be noted. Increased attention in the world press may have helped to create the high levels of reported activity that followed the devastating eruptions of Krakatau in 1883 and Mont Pelée in 1902. The authors suggest that a special observing effort made between 1951 and 1953 in Alaska by the U.S. Geological Survey helped to create a peak in the early 1950's. The disruption of normally reliable reporting of Indonesian eruptions after 1953 also helped separate it from a peak of the 1960's. The authors attribute dips in reported activity during the Great Depression and the two world wars to disrupted communications and distraction by more momentous events. "With the media attention devoted to the 1980 eruption of Mount St. Helens," they say, "we should expect to see another 'peak' of volcanism in the early 1980s." Not everyone agrees. Reid Bryson of the University of Wisconsin believes that the peaks and valleys of his volcanic record are real and that they correlate strongly over the past 100 years with changes in climate.

Even with the press sensitized to volcanic activity, the reporting of eruptions is far from foolproof, Simkin notes. On 9 August 1980, a few months after Mount St. Helens blew itself apart, a Northwest Orient pilot reported that Gareloi, an isolated volcanic island in the far western reaches of the Aleutians, had sent up a column of ash 10.5 kilometers high. That was not quite into the stratosphere, which meant that it rated a VEI of 3 when *Volcanoes* went to press. But on 10 August William Sedlacek of Los Alamos National Laboratory found a patch of unusually heavy volcanic debris in the stratosphere near Anchorage. On the basis of weather patterns and satellite photographs, he could track it back to Gareloi at an altitude of 19 kilometers. Since that is well into the stratosphere, the 1980 Gareloi eruption seems to deserve a VEI of 4, not 3. The compilers of *Volcanoes* emphasize that they welcome such corrections, which will appear in future editions.

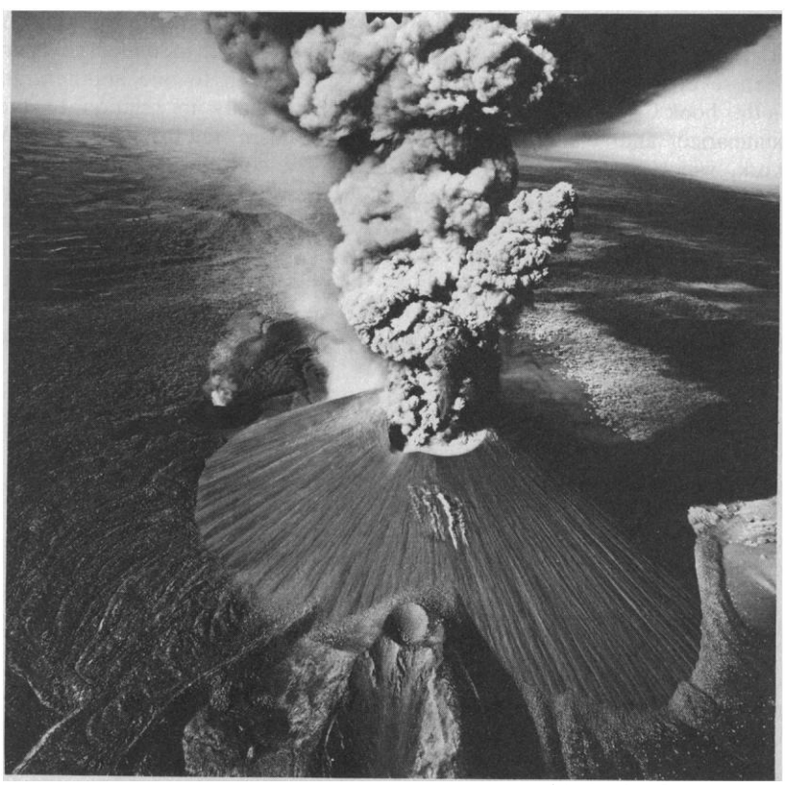
Although the record of global volcanic activity has been somewhat garbled, Simkin still thinks that the behavior of volcanoes is not totally random. One "intriguing" episode, he says, involved the eruption of Mont Pelée on Martinique in 1902 (VEI of 4). The eruption of Soufrière of St. Vincent (also a 4) 165 kilometers to the south preceded it by only 1 day, and the even larger eruption of Santa María in Guatemala (VEI of 6), 3260 kilometers to the west, followed it by 5 months. Simkin notes that these are the three most explosive historic eruptions to have occurred in the same year. In addition, these three were all on the edge of the same crustal plate, suggesting that stresses transmitted across a plate may trigger simultaneous volcanic activity over a large region (*Science*, 12 June, p. 1258).

The introductory text of *Volcanoes of the World* concludes on an ominous note. The longer a volcano remains quiet, the more explosive—and the more lethal—the next eruption may be. Most eruptions having VEI's of 0 to 2 had intervals of quiet preceding them of 1 to 10 years. Few of these eruptions involved fatalities. No eruption with a VEI of 6 had an interval of less than 100 years, and most had at least 1000 years, between eruptions. Sixty percent of the historic eruptions caused fatalities. The period of deceptive quiet is probably even greater, the authors warn, for the rare volcanic events that dwarf those in their catalog of the last 10,000 years. The American West has had its share of these. Seven hundred thousand years ago, for example, Long Valley Caldera near Mono Lake in California spewed 600 cubic kilometers of ash over an area of 1200 square kilometers. Mount St. Helens managed to eject about 1 cubic kilometer of ash.—RICHARD A. KERR

R. S. Fiske

Kilauea Volcano, Hawaii

1968 eruption of Halemaumau



Inter American Geodetic Survey

1968 eruption of Cerro Negro, Nicaragua