DIAMOND JUBILEE (1912—1987)

HVO

HAWAIIAN VOLCANO OBSERVATORY

Hawaii Symposium on How Volcanoes Work

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Introduction

The Hawaiian Volcano Observatory celebrated the Diamond Jubilee of its founding in January 1987. The 75th anniversary was commemorated with the dedication of a new Hawaiian Volcano Observatory building on 16 January 1987. The celebration continued the following week with an international scientific conference on How Volcanoes Work.

Background

The Hawaiian Volcano Observatory (HVO) was founded in 1912. The observatory is presently operated by the United States Geological Survey, Department of the Interior, and is located on the summit of Kilauea Volcano on the Island of Hawaii in Hawaii Volcanoes National Park. The observatory monitors the active volcanoes of Hawaii, providing warnings of potential eruptions and conducting fundamental research on volcanic activity.

The observatory was founded by Dr. Thomas A. Jaggar, a volcanologist with the Massachusetts Institute of Technology. Jaggar had been one of the scientists sent by the United States Government to investigate the disastrous eruption on 9 May 1902 of Mt. Pelée, Martinique, which destroyed the city of St. Pierre and its 28,000 inhabitants. Appalled by the devastation and loss of life, Jaggar felt that science must be able to find a way to mitigate such disasters, and following through, was convinced of the need for an American volcano observatory. At this time, there was only one volcano observatory in the world, at Vesuvius (Italy), established in 1847.

In 1909, Jaggar proposed the idea of an observatory "on the brink of the Volcano of Kilauea" to prospective financial supporters in Honolulu. Two years later, interested residents and businessmen formed the Hawaiian Volcano Research Association to support volcanic research in Hawaii through the establishment of a new Hawaiian Volcano Observatory. The traditional date of the establishment of HVO is 17 January 1912, the day Jaggar arrived at Kilauea to begin work as the director of the Hawaiian Volcano Observatory.

Jaggar set two major research goals for the observatory: to conduct systematic, scientific studies of the active Hawaiian volcanoes to understand more about volcanoes; and the practical application of research for mitigating volcanic hazards, including the forecast of impending eruptions and the identification of paths of potentially destructive lava flows.

HVO has been responsible for the development of most of the volcano-monitoring techniques now in use worldwide. In addition, the observatory also has served as a training centre for volcanologists from many countries.

Symposium

The Hawaii Symposium on How Volcanoes Work was held 18-26 January 1987, and was organized by Bob Decker, J.B. Halbig, Richard Hazlett, Reginald Okamura and Tom Wright. The Symposium was sponsored by the United States Geological Survey (USGS), University of Hawaii at Hilo, International Association of Volcanology and Chemistry of the Earth's Interior (IAVCEI), Circum-Pacific Council for Energy and Mineral Resources, Hawaii Institute of Geophysics, American Geophysical Union (AGU), the Geological Society of America (GSA), and the World Organization of Volcano Observatories (WOVO). The logo for the conference (reproduced, in reduction, at the top of this report) was designed by Ben Servino of USGS.

Twenty countries, in addition to the host nation, were represented by the approximately 450 participants who attended the eight days of talks, poster sessions, field trips and social events. In addition to the usual conference handouts (participants list, programme, 282-page abstracts volume), all participants received a copy of the just printed, two-volume USGS Professional Paper 1350 *Volcanism in Hawaii*. Edited by R.W. Decker, T.L. Wright and P.H. Stauffer, this impressive work contains 62 papers in 1667 pages, and is available from the USGS Printing Office in Denver ($95 US). Participants were then able to puzzle over how to get the 17-pound tome home.

The symposium opened on Sunday, 18 January, with an informal reception; the formal luau was saved for the closing ceremonies a week later. The intervening seven days alternated between all-day sessions and all-day field trips, with evenings devoted to poster sessions.

The lecture sessions, with complementary evening poster sessions, were entitled: Conceptual Models of How Volcanoes Work; Internal and Deep Structure of Volcanoes; Dynamics of Magma Chambers; Dynamics of Eruption and Intrusion Processes; Exploration of Submarine Volcanoes; Earthquakes and Tremor Related to Volcanism; Monitoring Active Volcanoes; and, Assessing Volcanic Hazards, Forecasting Eruptions and Reducing Volcanic Risks.

Rather than attempt to summarize the 270 oral and poster presentations at this symposium, two of the Canadian participants have prepared brief synopses of the research presented which would likely be of interest to *Geoscience Canada* readers. These synopses, in part, reflect their own research interests and deal with the subject areas of petrology, Precambrian volcanology and volcanic hazards.

Petrological Aspects of the Hawaii Symposium on How Volcanoes Work
(contributed by T.H. Pearce)

The petrological sections of the Hawaiian Symposium emphasized the international character of volcanic petrology. Papers were presented by petrologists from China, Russia, Japan and other Asian countries as well as from Europe and the Americas. Canadian representatives were present from University of British Columbia, University of Calgary, Guelph University, McMaster University, Queen's University, Acadia University, Geological Survey of Canada, provincial surveys and Lac Minerals. The organizing committee of R.W. Decker, J.B. Halbig, R.W. Hazlett, R. Okamura and T.L. Wright are to be congratulated on such a successful meeting.

Papers on the same theme were grouped together and general observations on the symposium are as follows. A series of papers were presented on aspects of the current eruption of Puu Oo (active since 3 January 1983) and this was combined with an interesting field trip to the Kalapana Flow which has destroyed some houses. The lava of this flow is said to be differentiated beyond "olivine control" implying storage and crystal fractionation within the East Rift zone of Kilauea.

The statement "all volcanism is basaltic volcanism" still seems to be operative, and zoned magma chambers and magma mixing continue as popular topics. The commonly assumed ferrous/ferric ratio may not be correct as D.M. Christie and co-workers showed (in an abstract) that the glasses of mid-ocean ridge basalts are much more reduced than whole rocks. Numerical modelling by computer simulation continues to grow in importance. Indeed, four of the five Canadian petrological papers presented at the meeting used this technique.

The Canadian contribution to the petrology of this Symposium was varied, reflecting the breadth of interest in this field. Topics ranged from the thermodynamics of magmas to zoned crystals and Archean subaqueous pyroclastic volcanism. Some of the major points of the Canadian contributions are highlighted below.

J. Nicholls and M.Z. Stout of the University of Calgary presented their recent studies on the 1967-68 eruptions of Kilauea giving evidence for picritic melts. They established the co-magmatic nature of the 1967 Halemaumau summit eruptions with the 1968 Hiiaka Crater eruptions. Rigorous testing of competing hypotheses was accomplished using a combination of thermodynamic modelling and major element ratio trends in Pearce element ratio diagrams — the latter establishing a chemical fingerprint of the fractionation process. Their results are consistent with olivine fractionation from a picritic liquid and this is an important and far-reaching conclusion.

J.K. Russell of the University of British Columbia developed his thermodynamic model of magmatic processes in a well-received poster session. Using earlier work of Nicholls and Ghiorso, he calculated a model ascent path in P-T space for the observed phenocryst assemblage of the 1984 Mauna Loa eruption. The calculated path in Russell's approach is constrained by the phase assemblage. Ancillary calculations determined the mineral chemistry, residual melt composition and net energy balance dictated by crystallization and vesiculation.

Precambrian subaqueous pyroclastic volcanism has been studied by R.M. Easton, G.W. Johns, T.L. Muir and P.C. Thurston of the Ontario Geological Survey. They detected no fundamental difference between Precambrian and recent volcanic systems. Their work, derived in part from earlier studies of Lorne Ayres, relies heavily on facies models, stratigraphic correlation, and very detailed mapping. The Precambrian volcanoes in this study are located in some areas of considerable economic interest (Timmins and Hemlo, for example) and are part of an on-going project of interest to both practical and theoretical petrologists.

R.S. Hildebrand of the Geological Survey of Canada reported studies of a dioritic early Proterozoic continental intrusive complex in the northwest part of the Canadian Shield. Field and petrographic studies indicate that crystal settling of plagioclase was probably the dominant fractionation mechanism. Using computer simulations, settling velocities were estimated to have varied from one to 160 meters per year.

T.H. Pearce, along with co-authors M. Griffin and A. Kolisnik of Queen's University, presented their latest work on the interpretation of crystal zoning profiles. Using zoning patterns produced by laser interference microscopy and applying statistical analyses it is possible to place constraints on the value of some of the magmatic parameters during crystal growth. In particular, they showed that individual episodes of growth in complexly zoned plagioclase may be treated as cases of simple, normal zoning from a very small system. The zoning patterns of olivine crystals in which zoning is preserved appears to be a case of simple, normal zoning.

A Precambrian Perspective
(contributed by R.M. Easton)

Only two presentations at the symposium dealt specifically with Precambrian volcanism, however many oral and poster presentations during the course of the symposium presented data or conclusions that have a significant bearing on the study and understanding of Precambrian volcanic systems.

R.S. Hildebrand of the Geological Survey of Canada, through detailed petrographic and chemical studies of a Proterozoic sub-volcanic intrusion, was able to show that crystal settling is an important mechanism of fractionation within sub-volcanic systems, but his speculations on Rayleigh numbers led to some criticism from the floor. R.M. Easton, G.W. Johns, T.L. Muir, and P.C. Thurston of the Ontario Geological Survey (OGS) presented a poster which synthesized their understanding of subaqueous pyroclastic volcanism, particularly in silicic systems, based on work done by the OGS in Ontario over the last five years. Included was an idealized model of a typical subaqueous volcano.

On a more general note, there were a number of studies and areas of consensus which emerged during the meeting of relevance to geologists and volcanologists working in the Precambrian. A major conclusion that came out of the symposium was that each volcano has a specific, individualistic magma system that is the product of fundamental geologic processes (*e.g.*, magma generation, ascent, crystal fractionation, *etc.*), yet has attributes which reflect local conditions (*e.g.*, host rock lithology, local tectonics, regional tectonic setting, *etc.*) It is these local conditions which play a major role in the development of the volcano's magma chamber, and hence the nature and location of its eruptions. This makes it difficult to make broad generalizations between volcanoes, but it does allow for a great deal of variety in volcanic activity and products in a given tectonic setting. At first it might appear that this makes it more difficult to study Precambrian volcanoes, which are commonly metamorphosed and deformed, however, all is not hopeless, since, in some instances, it is possible to make some generalizations within volcanic belts. Shigeo Aramaki (U of Tokyo), in a review of the volcanic belts of Japan, found some broad similarities between the volcanoes of the Japanese Islands, particularly in the nature of the magma chamber and chemistry. M.J. Carr (Rutgers U) and others, and S.P. Halsor and W.I. Rose (Michigan Tech.) reported on distinctive characteristics of Central America arc volcanoes, including the presence of paired volcanoes. In both areas, similarities exist between volcanoes in a particular region, but major differences exist between Japanese and Central American arc volcanoes, undoubtedly reflecting local geology and tectonics. Thus, one must use caution when using a particular modern-day example when comparing modern and ancient volcanoes and volcanic belts. Lack of detailed data sets for modern volcanic belts at present further hampers comparison between ancient and modern volcanic regimes.

With respect to large basaltic magma systems, both flood basalts and shield volcanoes, it is apparent that such systems can erupt huge volumes of relatively homogeneous magmas quickly, and for long periods of time. In the case of flood basalts, Peter Hooper (Washington State U) summarized the latest ideas on the Columbia River basalts. Eruptions occurred at intervals of 10,000-20,000 years, although individual eruptions consist of 1000-1400 km^3 of lava (in 4 years from 1983-87, Kilauea has only erupted 850 km^3 of lava) erupted over periods of days, and that the lavas are chemically homogeneous over great distances (*e.g.*, 600 km^2 in the Ponoma Flow). Only large, well-mixed magma reservoirs can produce such flows. Similar results were reported by M. Rhodes (U of Massachusetts) who has been examining the geochemistry of Mauna Loa lavas erupted during the last 30,000 years. He found little change in chemistry with location, time, or apparent eruption rate. Those of us working in the Precambrian commonly see large volumes of chemically similar lavas, and it is now apparent that such accumulations are to be expected. Also, different tectonic settings can produce the same result; it is magma reservoir size that seems to be the critical factor.

Gail Mahood (Stanford U) addressed the question of why plutons associated with compositionally zoned ash-flow sheets are not compositionally zoned, even though they represent the now crystallized magma chamber. Her answer was that slow cooling obliterated the compositional zonation because of inward-directed crystallization from the walls of the chamber and continued convection. Only rapid cooling would preserve a compositionally zoned chamber. This is certainly an area of study where workers in Precambrian terranes can contribute, since we commonly have the exposures necessary to see both the crystallized magma chamber and its eruptive products. P. Lipman (USGS-Denver) also examined the deeper levels of silicic caldera systems, and noted that there is a feedback mechanism between eruptive processes, tapping of the magma chamber, and subsidence of the system. For example, in the Bachelor Caldera in the San Juan volcanic field, collapse of the caldera walls affected the emplacement of one of the ash-flows during eruption. The net effect as far as we are concerned is a very complicated stratigraphy, and a number of different facies representing a single eruptive event. Such complications are likely to be present in Precambrian volcanoes, and may be difficult to unravel in areas of incomplete exposure.

Ui (Kobe U) and others studied petrofabrics in pyroclastic flows in Japan to see if grain orientation only occurs in the core of the flow unit; it is best develped in welded flows; is best developed near the vent, and is only radial near the vent; and the fabrics commonly parallel valley and ridge direction. Such fabrics appear of limited use in determining flow direction in recent, let alone ancient, volcanic systems.

On a more personal note, I found that the work by Juergen Kienle (U of Alaska) and T.P. Miller, M.E. Yount, and S.W. Nelson (USGS-Anchorage) on Augustine Volcano in Alaska of particular relevance to my research in the Precambrian. This island stratavolcano erupted in 1986, producing both pyroclastic flows (over 200 in 100 hours) and a lava dome. The former produced a pyroclastic apron around the volcano, and dome collapse in the past has produced debris avalanches into the adjacent marine setting. Augustine may in fact be typical of some Archean volcanoes, particularly those characterized by lava domes, and by a variety of subaqueous pyroclastic flow and volcaniclastic deposits. Unfortunately, the off-shore deposits of Augustine remain unstudied.

Some points of a more general nature are that integrated studies, combining geochemistry, geophysics, petrology and stratigraphy are being done more often, leading to a better understanding of the magma reservoir and eruptive mechanism of the volcano. Such studies can be utilized in the Precambrian, even though we are attempting to reconstruct the past behaviour of a volcano, especially now that a number of well-studied volcanoes can be used for comparison. Also, although a few volcanoes are well-studied (*e.g.*, Kilauea, Mt. Etna, Mt. St. Helens), we still have only limited information on many volcanoes, and even less on regional volcanic belts. This hampers our ability to compare modern and ancient volcanoes.

As a final note, it was most enlightening to learn that, in some ways, we are equals with our co-workers studying recent volcanoes. For example, researchers on a deep-sea drilling leg were asking me how to differentiate between distal subaqueous pyroclastic flows, airfall tuffs and volcanic sediments, which they had in drill-core. Our perspective in Precambrian terranes is similar in some ways to those who must examine the Recent by remote sensing methods or through drill-core. Thus, volcanologists working in the Precambrian should not feel at a disadvantage, but as equals with those working in the Recent; both groups are working toward the goal of finding out how volcanoes work.

Volcanic Hazards Research

It was only fitting that the latter part of the conference dealt with one of the major research goals of Dr. Jaggar, namely, the practical application of mitigating volcanic hazards and forecasting impending eruptions. Although the sessions on "Monitoring Active Volcanoes" and "Assessing Volcanic Hazards, Forecasting Eruptions and Reducing Volcanic Risks" dealt with these questions in particular, talks and poster in the other sessions were also related to these subjects. Further, two of the informal evening sessions dealt with these subjects as well.

During one evening session, Maurice and Katia Krafft presented a film they had made on "Volcanoes of the Americas". The purpose of this film was two-fold. First, it was designed to make the public more aware of the types of volcanoes present in the Americas and the types of hazards that they presented. Second, it was made to illustrate what these hazards are. As scientists, we banter about terms such as lahar, mudflow, pyroclastic flow with great abandon, yet the general public does not have any idea of what these volcanic products are, or how they can devastate an area. In the Krafft's film, they reconstructed the events leading up to the 1902 Martinique eruption by using footage from more recent eruptions, and produced an excellent depiction of that eruption and the types of hazards it produced. We might see more of these techniques used in future, particularly for educating people in underdeveloped nations.

Another evening was devoted to informal presentations on recent volcanic eruptions, such as the 1986 (and continuing) eruptions of Izu Oshima in Japan. This was followed by a presentation of the preliminary investigative report on the 1986 Lake Nyos gas disaster in Cameroon, subsequently published in *Science* (v. 236, p. 169-175, 1987). The presentation included graphic film footage of the disaster, and the devastation it caused, images not generally seen by the public.

The greatest hindrance to volcanic hazard assessment at most volcanoes is the lack of active monitoring, a limited historic record, or only a very basic knowledge of the local geology and volcanic history. Based on the survey at the meeting, only a few areas such as Hawaii, Japan, Etna, Naples, New Zealand and Rabaul are well-monitored. Many other areas, which present great risks, are still poorly studied. Indonesia is a good example of this latter situation, in that it has a large number of active volcanoes and has a large populated. However, many volcanoes have yet to be studied in detail or to be monitored, although many do have long historic records. Papers by Frank *et al.*, Casadevall *et al.*, Matahelumual *et al.* and Bronto dealt with the Indonesian situation, and, for the most part, represent collaborative efforts between the Geological Surveys of Indonesia and the United States.

An interesting attempt to get around the problem of limited data was given by Saint-Ours, who was able to extend the elevation data record (reflecting magma chamber inflation) for Rabaul back 40 years through the use of raised intertidal shell horizons, and show that recent elevation increases at Rabaul have actually occurred over a much longer time span than previously recognized.

Scandone, Sartoris *et al.* and Luongo presented data on the potential volcanic hazards in the Naples area of Italy, which is particularly frightening from a volcanic hazards viewpoint. Specifically, over the last thousand years, Vesuvius has exhibited plinian, subplinian and strombolian activity with lava flows. As a result, three different volcanic hazards maps had to be produced for the region for each of these three eruptive types. In this case, the nature of the eruptive activity needs to be predicted, as well as the eruption, for accurate risk assessment.

As discussed by Scott and Miller, cataclysmic eruptions produce a variety of effects: (i) *proximal effects* which devastate tens of thousands of square kilometres — areas which need to be evacuated in order to save lives, sometimes involving millions of people; (ii) *distal effects* at distances of 100 km and more which can affect agriculture, transportation, *etc.*, but which are harder to mitigate; and finally (iii) *global effects*, which ultimately would affect grain production and result in famine. In this case, only long-term planning can have any mitigating results.

Yount and Miller and Swanson and Kienle dealt with various hazards related to the 1986 eruption of Mt. St. Augustine in Alaska. A particular problem here was the effect of ash on air travel. Volcanic hazard assessment problems were also discussed in relation to Kamchatka volcanoes (Tokarev), Hawaii (Moore *et al.*, Lockwood), Mt. St. Helens (Scott and Janda, Swanson *et al.*) and on more general themes.

The effects of volcanic hazards were also brought home on the field trips associated with the meeting. Participants viewed the destroyed homes, buried cars and streets, *etc.*, near Kalapana caused by the November-December 1986 Kilauea lava flows. On the Mauna Loa-Mauna Kea trip, we viewed a historic rock wall which had temporarily diverted a lava flow, and discussed diversion barriers such as the barrier built around the Mauna Loa atmospheric laboratory to prevent its destruction by future Mauna Loa flows.

It was most appropriate that the last talk in the session, and of the meeting, by Don Peterson (USGS), dealt with the relationships between scientists, the media, the public and hazardous volcanoes. This brought home the problems of communicating scientific information to the public in a reasonable and responsible fashion, as well as presenting the other point of view, namely what people wish to know *versus* what the scientists think they should know.

This is only a brief overview of the complexities associated with the subject of Volcanic Hazards Assessment and Mitigation. If anything, we learned that we have a lot of work to do before we can make predictions in areas that are well understood, and even more to do in many parts of the world where hazards are particularly high. However, the more we understand "How Volcanoes Work", the closer we come to reaching the goals toward which Jaggar was striving.