

feature article

The origin of the Hawaiian Volcano Observatory

John Dvorak

In 1912 Thomas Jaggar left MIT to start an observatory on the remote Kilauea volcano. The move was the culmination of a tortuous chain of events.

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A hand-colored lantern slide of a 1919 photo taken by Thomas Jaggar shows lava flow on Mauna Loa, one of four active volcanoes under the purview of the Hawaiian Volcano Observatory. (Image courtesy of Hawaii Volcanoes National Park.)

I first stepped through the doorway of the Hawaiian Volcano Observatory in 1976, and I was impressed by what I saw: A dozen people working out of a stone-and-metal building perched at the edge of a high cliff with a spectacular view of a vast volcanic plain. Their primary purpose was to monitor the island's two active volcanoes, Kilauea and Mauna Loa. I joined them, working for six weeks as a volunteer and then, years later, as a staff scientist. That gave me several chances to ask how the observatory had started.

Each person I asked told the same simple story—that early in the 20th century, Thomas Jaggar, head of the geology department at MIT, visited the Hawaiian Islands and made the journey to the summit of Kilauea, where he saw a rare lake of molten lava (see cover photo). Intrigued by the sight, he left MIT, moved to Kilauea to start the observatory, and devoted the remainder of his life to a study of volcanoes.

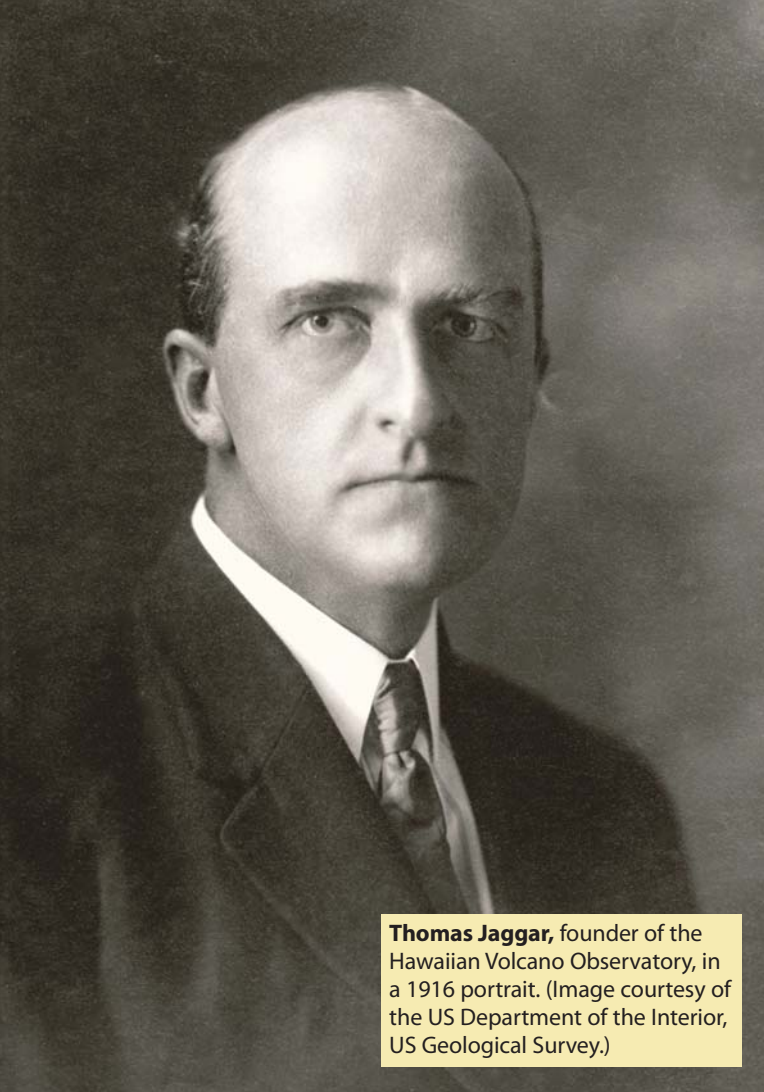
It is a nice story, but one I never wholly accepted. Who

would make such a dramatic decision without other forces at work? Many others, including such notable geologists as James Dwight Dana, Clarence King, and Reginald Daly, had seen the remarkable lava lake, but none of them took the drastic step that Jaggar did. Something more compelled him.

For 35 years I've sifted through newspaper clippings, letters, and Jaggar's own writings to figure out what that something was. Now, as the observatory's 100th anniversary draws near, it is fitting to recount the sequence of events that led Jaggar to Kilauea and what he did once he got there.

A Caribbean catastrophe

The big news story of 1902 was the explosion of the volcano Mount Pelée on the Caribbean island of Martinique and the resulting deaths of tens of thousands of people in the city of Saint-Pierre. Jaggar, then 31 and an instructor at Harvard University, was the youngest of five scientists sent by the US



Thomas Jaggar, founder of the Hawaiian Volcano Observatory, in a 1916 portrait. (Image courtesy of the US Department of the Interior, US Geological Survey.)

to investigate the eruption. Long before the era of big armaments and atomic blasts, the idea that an entire city and all its inhabitants could be destroyed in a matter of minutes was still a foreign one. (In contrast, the ancient city of Pompeii was buried by ash and cinders over the course of hours.) When the five scientists arrived, they were understandably shocked by what they saw. Most surprising was the number of bodies. Dead men, women, and children were everywhere.

Jaggar wrote of finding a dead baby in a cradle and the body of an elderly man face down in an empty water tank. Inside a ruined bakery he found the body of a man, most likely the baker, who had sought refuge from the eruption by climbing into a cold oven. Hot volcanic ash had surrounded the bakery and cooked him inside his own oven. Deeply disturbed, Jaggar wrote of Saint-Pierre, "The odor was a haunting one that returned in dreams—of foundry, steam, sulfur matches, and burnt stuff, and every now and then a whiff of roast, decayed flesh"¹ (p. 57).

After Saint-Pierre, Jaggar sailed around the Caribbean, collecting and measuring the depth of ash deposited by both Mount Pelée and the nearby volcano Soufrière, which had exploded nearly simultaneously. While on Barbados, he heard that two survivors of the Mount Pelée eruption were at a local hospital. He went to see them.

The survivors—Clara King, a family nurse, and her charge, 14-year-old Margaret Stokes—had been on the steamship *Roraima* in Saint-Pierre's harbor when Mount Pelée exploded. When Jaggar met them, the girl still had deep burn scars on her head and along both arms and legs. One ear was

greatly disfigured. He thought she would be crippled for the remainder of her life. The nurse had fared better, and had bandages only on one arm and around both knees. Jaggar asked her what she had seen and heard during the eruption.

King told him the sea had been calm and no sound came from the volcano before it exploded. The eruption itself began "like a terrific clap of rattling thunder all at once, and then no more." A black cloud rose from the summit, perched for a few seconds on the edge of the crater, then slid down the side and raced toward Saint-Pierre. As soon as the cloud hit the ship, everything became dark and hot, King said, and she wished she would die.²

What King had seen was a *nuée ardente*—literally, glowing cloud—a mixture of superheated steam, ash, and rocks that moved at hurricane speed. Jaggar would be one of the first to describe the then-obscure phenomenon and explain its underlying physics. Still, as he would later write, "It was the human contacts not the field adventures which inspired me."

He was devastated by the story of King, a frail woman destined for a life of servitude, who had suffered unimaginable horror. And so he was decided. When he returned to Harvard, he announced that he would devote himself to a study of volcanoes, calling it "a missionary field because people in it were being killed"¹ (p. xi). But how to proceed?

An American in Italy

Soon after he returned from the Caribbean, Jaggar was appointed an assistant professor at both Harvard and MIT, two institutions that were then negotiating a merger. He also married Helen Kline, the 22-year-old daughter of a San Francisco banker. Jaggar's father, a bishop of the Episcopal Church, performed the ceremony.

Two years later, on 7 April 1906 and just months after the birth of the Jaggars' first child, Vesuvius exploded. The eruption would prove its biggest in almost 300 years, and Jaggar was determined not to miss it. He left immediately but didn't arrive at Vesuvius until 24 April, two days after the Italian government officially declared the eruption over.

Undeterred, he proceeded up the side of the volcano, riding a small electric train that usually carried tourists to a hotel near the summit. At the end of the line he saw the hotel, demolished. Next to it was a massive stone structure that housed the Vesuvius Observatory—the first and, at the time, only such institution in the world. Every window was broken, but the building was intact. Behind it, descending from the summit above, was the American engineer Frank Perret.

Born in Brooklyn, Perret had once worked improving batteries and designing low-torque electric motors for Thomas Edison. In 1902, while suffering from a breakdown in health, Perret learned of the disaster at Saint-Pierre. It inspired him to apply his knowledge of electrical devices to a study of volcanoes. He moved to southern Italy to be near Vesuvius and to recuperate in the mild Mediterranean climate. In 1905, when Vesuvius started to erupt in its buildup to the 1906 explosion, he convinced the director of the Vesuvius Observatory to let him work as an unpaid assistant. The American engineer built a variety of microphones and seismographs to record the increasing activity.³ He showed the instruments and recordings to Jaggar, who was notably impressed. "The world's greatest volcanologist"¹ (p. xi), Jaggar called him.

In fact, Jaggar was fascinated by the very idea of the Vesuvius Observatory, which started in 1848 as a magnetic and weather station and later expanded to include observations of volcanic activity. Jaggar thought that if a network of such stations—he called them geonomical observatories—could be established, then much could be learned about

Earth, and future disasters like Saint-Pierre might be prevented.

Expedition to Alaska

The next summer, attempting to get his volcano studies under way, Jaggard led a small party of scientists on a four-month cruise of Alaska's Aleutian Islands, the world's longest chain of volcanoes. He visited several islands, but the high point was a six-hour landing on Bogoslof, a steaming crag that had recently risen from the sea. While on the small rocky island, Jaggard noticed that several beaches and wave-cut terraces were well above sea level, an indication the island was still rising. Three weeks later, Bogoslof exploded. The captain of a ship that passed by after the eruption reported that the crag was gone and in its place was a steaming lagoon whose "waters were in a state of constant ebullition."⁴

Back in Boston, Jaggard would describe Bogoslof as "an island that changes form while you wait."⁵ He wondered aloud where else "this old earth [was] pushing up and down its shore lines . . . building other Bogoslofs."⁴ Such a question could not be answered by searching through libraries and museum collections or by leading an occasional expedition. It required the prolonged efforts of an experienced observer who could record earthquakes and recognize subtle changes in volcanic conditions. What Perret did at Vesuvius, Jaggard would do in the Aleutians.

His plan got a boost in August 1908 when he received an inheritance after his mother died. It left him with enough money to resign his MIT professorship—by then he had already left Harvard—and work in Alaska for a few years. But his wife objected. He had a family to consider, she said. And they were still sharing a rented house with another couple; they needed to purchase a place of their own.

After some reluctance, Jaggard acquiesced, but on the condition that they also take a trip. The couple settled on Japan, a country that had recently opened its borders to foreign travelers—and a country that had many volcanoes. On their way across the Pacific Ocean, they would stop in the Hawaiian Islands and see the lava lake at Kilauea.

The Hawaiian Islands

On 28 December 1908, two months before the Jaggards left for the Hawaiian Islands and Japan, a strong earthquake shook the southern Italian town of Messina, killing more than 100 000 people. Jaggard found the moment opportune to promote his idea of building geonomical observatories. In public lectures, he described the proposed work as "epoch-making in the history of science" and asked if anyone was willing to provide money to support it. Someone was.

The trustees of the Edward and Caroline A. R. Whitney Estate of Boston, a philanthropic group that often contributed to cultural activities in the city, announced that they would donate \$10 000 to MIT to construct a geonomical observatory. Their only condition was that the observatory be located near Boston.



Playing with fire. Thomas Jaggard, crouched at front in this 1917 photo, holds a pipe used to facilitate temperature measurements of the molten lava lake inside the Halemaumau crater on Kilauea. Behind him, third from the right, is Lorin Thurston, another key figure in the establishment of the Hawaiian Volcano Observatory. (Image courtesy of the US Department of the Interior, US Geological Survey.)

With that promise of financial support, Jaggard and his wife departed Boston for San Francisco, and then sailed to the Hawaiian Islands. They arrived in Honolulu on 1 April, stayed one night in the city, and left the next morning on a small steamer for Hilo on the island of Hawaii. A few other volcano-bound passengers were on board. The sail was a rough two-day passage over a rolling sea.

In Hilo, a train took the Jaggards and the others partway up Kilauea. There they transferred to buckboard wagons, which carried them the remainder of the trip. In all, the 30-mile trek—first through fields of sugar cane, then through a dense forest of giant ferns and hardwood trees—took six hours. It ended on the doorstep of the Volcano House, a modest hotel with a magnificent view of Kilauea's summit. Of particular interest to Jaggard was a column of steam rising from a circular pit crater, Halemaumau, three miles away.

Jaggard walked the well-worn path to the edge of Halemaumau on each of the three days he and Helen stayed at the hotel. The crater was a quarter mile in diameter, with steep inner walls that made descent impossible. At the bottom of the crater, 200 feet below the rim, was a gray metal-like surface made up of large, irregular slabs of solidified lava.

The slabs, separated by lightning-like cherry-red lines of molten rock, were in constant motion. Occasionally two slabs would collide, one plunging beneath the other, and send a jet of molten material into the air. The disturbance would send waves of orange-red molten material rolling across the entire surface of the lake. After a few minutes, the lake would calm, the surface would cool, and the slabs would reform. It was a stupendous sight that visitors would eagerly describe to friends and family when they returned home. Jaggard's description, however, was more poignant than most—for him it was "as if everything within me converged"¹ (p. 77).

A grand vision

Jaggard saw Kilauea as a great natural laboratory—preferable to the solemn halls of academia—where scientists could con-

gregate to learn about Earth. The lava lake had persisted for most of the past century, so scientists were almost guaranteed to have molten material to study; the volcano was in a tropical clime, which made it accessible year-round; and its eruptions were relatively benign. For all those reasons, Kilauea was potentially the ideal place to develop observational techniques that could then be applied to other volcanoes. But how could Jagggar convince anyone to build an observatory in such a remote place?

The Jagggars returned to Honolulu, where they waited a few days for the next ship to Japan. On their last day, Jagggar gave an invited lecture at the University Club of Honolulu. He started by showing lantern slides of the destruction of Saint-Pierre, and then told of his experiences at Bogoslof and of the courageous work being done by Perret at Vesuvius. He ended by announcing that a station for volcano research would soon be established near Boston, thanks to the private gift from the Whitney Estate.

After the presentation, a reporter from Honolulu's *Pacific Commercial Advertiser*, the islands' largest newspaper, asked Jagggar whether Kilauea might be a better place than Boston for a research station. Jagggar answered yes. "Is it a matter of money?" the reporter asked. Largely, Jagggar responded, but it was also a matter of persuading people in Boston to shift their focus to Hawaii. The reporter, Lorrin Thurston, who owned the *Advertiser*, invited Jagggar to stop in Honolulu on his return trip across the Pacific so that they might talk more about the matter.⁶

After two weeks in Japan, where Jagggar visited several volcanoes, he and Helen returned to Honolulu. Thurston ushered him to a meeting with the territorial governor, who assured the professor that any work he might do at Kilauea would have the full support of the islands' business and political communities. Jagggar, impressed by the enthusiasm and confident that he could redirect the Whitney fund, promised to return in a few months to begin the work of a permanent observatory.

But as soon as he reached Boston, he met resistance. Neither MIT president Richard Maclaurin nor MIT treasurer Charles Stone, who was a trustee of the Whitney Estate, approved of work at Kilauea. "It would be wise to postpone ac-

tion," Maclaurin wrote to Jagggar in a private message. Stone was more direct, saying that he "had some doubt about the wisdom of establishing a Hawaiian observatory." The islands were too distant and the proposed work was beyond the scope of the institute.⁷

Unable to win support from Maclaurin or Stone, Jagggar made a personal appeal to Caroline Whitney. He laid out his plan for Kilauea, saying that if she increased her gift 10-fold he could establish geonomical observatories around the world. The 84-year-old Whitney was taken aback. She told him she had already been generous. The next day, Maclaurin and Stone discussed the matter with her and convinced her to raise the donation to \$25 000. Still, as they told Jagggar soon thereafter, any future work at Kilauea was yet to be decided.

The promoter

Thurston had personal reasons for wanting a volcano observatory at Kilauea. First, he was an avid volcano watcher. A former owner of the Volcano House, he had seen several major collapses of the lava lake; he once stood at the crater's rim for 20 hours watching as the lake dropped 200 feet.⁸

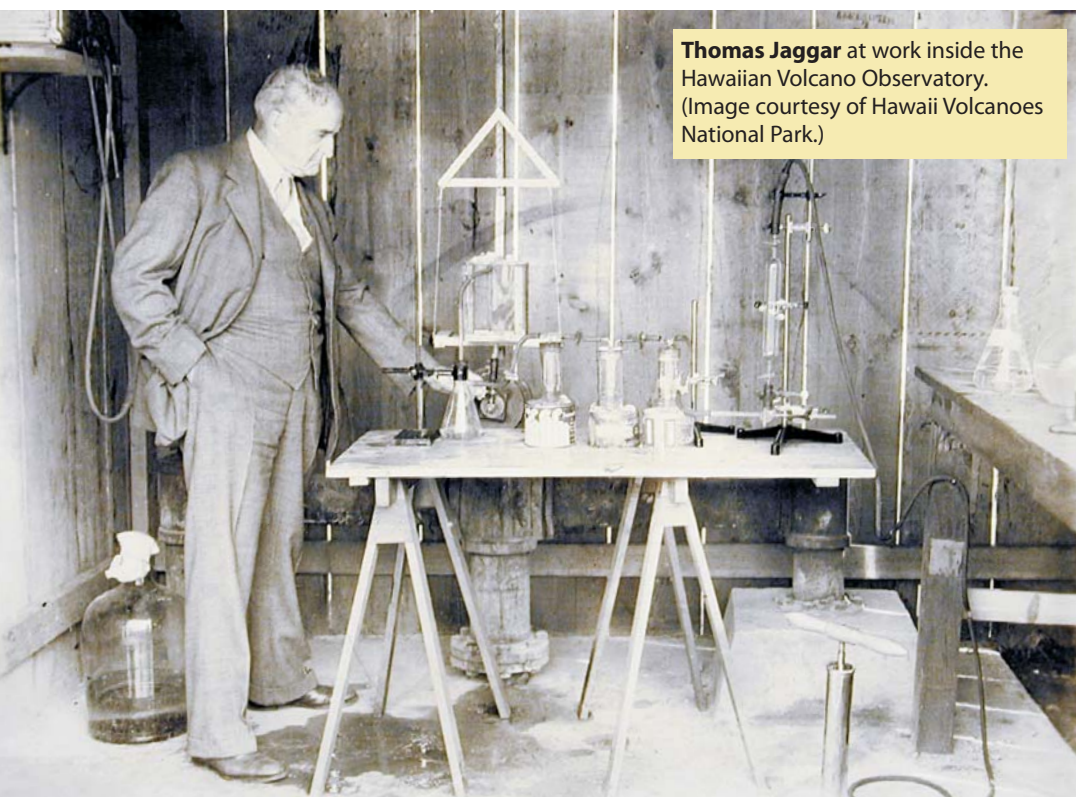
Thurston also saw the volcano as a business venture. He owned the train that Jagggar had ridden to Kilauea, and he was maneuvering to buy back the Volcano House. His grand plan was to make Kilauea one of the scheduled stops for the increasingly numerous passenger ships crossing the Pacific. If someone wanted to see the lava lake, that person had to ride his train; if anyone wanted to stay overnight, his hotel would provide the only available accommodations.

After Jagggar returned to Boston, Thurston kept him informed of the activity of the lava lake. Jagggar, in turn, pressed Maclaurin and Stone to decide about the work at Kilauea. They and Caroline Whitney eventually agreed to convert the Whitney fund to an endowment and to allow Jagggar to use the interest accrued the first year—about \$1000—at Kilauea.

Jagggar hired Arthur Day, the director of the Carnegie Institution of Washington's geophysical laboratory, to design and build a sensor that could be lowered into Halemaumau to measure the temperature of molten lava. He asked Perret to join him the next summer at Kilauea to do the measurements. Preparations were well under way when Jagggar had to cancel his participation. Helen was again pregnant.

Perret did go to Kilauea and, with Thurston's help, made one reliable temperature measurement, which Thurston announced on the front page of his newspaper: "Temperature of lava recorded—heat 1010 centigrade."⁹ Perret stayed two more months, living in a wooden hut at the crater's edge and keeping the lava lake under constant surveillance. At the end of that tenure, and with Jagggar's approval, Thurston tried to persuade Perret to stay and start the work of a permanent observatory. Perret declined, not wanting to confine himself to working only on Hawaiian volcanoes. And so Thurston shifted his attention back to Jagggar.

On 17 January 1912, 11 weeks after the birth of his



Thomas Jagggar at work inside the Hawaiian Volcano Observatory. (Image courtesy of Hawaii Volcanoes National Park.)

daughter, Jaggar was back at Kilauea with permission from Maclaurin to remain for a few months. He raised money from Hilo businessmen to construct a small wooden observatory near the Volcano House. He went almost daily to the edge of Halemaumau to monitor the lava lake. He made a partial ascent of Mauna Loa in search of access to its 14 000-foot summit. And he met dozens of people whose support he would need to operate an observatory. He was working at a hectic pace when a telegram arrived from his wife: "The children are sick—Helen."¹⁰

Back in Boston, and satisfied with the health of his children, he met with Maclaurin, who said he was opposed to further work at Kilauea. Thurston then played his hand. Through cablegrams, he informed Maclaurin that he had raised enough money to pay the salaries of Jaggar and an assistant and to operate the observatory for five years. Furthermore, he was willing to cede all control of the observatory to MIT, if Jaggar returned immediately. Otherwise, scientists from the Bishop Museum in Honolulu and from the newly established College of Hawaii were ready to do the work.

On 22 May 1912, with the approval of the executive committee, Maclaurin "relieved Jaggar of other academic duties here for a period of five years, and appointed him to the office of the Director of the Hawaiian Volcano Observatory at Kilauea."¹¹ Jaggar returned to the volcano in late June. The official beginning of the Hawaiian Volcano Observatory was 1 July 1912, the day Thurston began to pay Jaggar's salary.

Legacy

Helen Jaggar and the two children arrived five months later. The Jaggar marriage had always been a difficult one, and the remoteness of Kilauea ended it. Helen and the children left after six weeks and the Jaggars divorced. He seldom saw her or their children again.

Just three years after the observatory was officially established, Maclaurin notified Thurston that MIT would soon disassociate itself entirely from the project, in part due to rumors of Jaggar's "domestic infelicities and allied troubles."¹² Whether or not the rumors were true is unknown, but in September 1917 Jaggar married Isabel Maydwell, a widowed schoolteacher from California who shared the work of the observatory and who had become as capable at operating equipment and reading seismographs and as astute an observer of volcanic activity as Jaggar himself.

Thurston kept his word and supported Jaggar and the observatory for five years. After that, Herbert Gregory of Yale University tried unsuccessfully to take control and oust Jaggar. For two years after that, Jaggar worked without pay, until 1919, when the US Weather Bureau accepted the volcano observatory as a weather station. It became part of the US Geological Survey in 1924, was transferred to the National Park Service in 1935, and then was transferred in 1947 back to the USGS, under whose authority it remains today.

The workhorse instrument during the early years of the observatory was a Bosch–Omori horizontal seismograph. (See the box below.) On the afternoon of 25 November 1914, it began to record a series of small earthquakes, alerting Jaggar to the possibility of an eruption of Mauna Loa. No one on the island reported feeling the earthquakes. Six hours after the first earthquake was recorded, Mauna Loa did erupt. To my knowledge, it was the first entirely instrument-based detection of a buildup to an eruption.

The Bosch–Omori seismograph also worked as a tiltmeter. From 1917 to 1924, it recorded several cycles of gradual uplift, followed by rapid subsidence and eruption of lava. That basic pattern—slow filling of a shallow magma reservoir, then eruption—has been the subject of many grade-school science projects and is the foundation of the modern prediction of eruptions.

The Bosch–Omori seismograph

In 1912 there were 51 seismographs in the US. Nineteen were based on a design by Japanese seismologist Fusakichi Omori and manufactured by the firm J. and A. Bosch of Strassburg, Germany. Those Bosch–Omori seismographs, including the one that Thomas Jaggar eventually installed at Kilauea, were the gold standard of seismic instrumentation in that era.¹⁶

The innovation of the Bosch–Omori design was a heavy weight, or steady mass (labeled A in the figure), suspended from the top of an iron pier by two strong wires and held away from the bottom of the pier by a freely pivoting horizontal beam (L). The pier was firmly secured to the ground, so that seismic motions perpendicular to the pivoting beam would cause the assembly to oscillate as a horizontal pendulum. Seismic motions were recorded via a long arm (C) that extended horizontally from the heavy mass. A stylus (B) attached to the end of the arm scratched its motion onto a slowly rotating drum covered by smoked paper (T). Two identical contraptions were set up orthogonal to each other to measure both horizontal components of passing seismic waves.

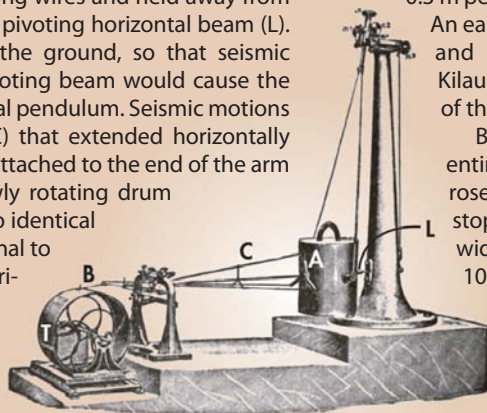
The Bosch–Omori seismograph could also register slight tilting of the ground surface. Just as the resting position of a hinged door shifts if a building tilts, the resting position of the steady

mass changes if the ground tilts. The instrument at Kilauea was sensitive enough to record shifts of less than 1 μrad —that is, a rise of less than 1 mm across a distance of 1 km.

The data gathered from the Hawaiian Volcano Observatory's Bosch–Omori seismograph yielded many tantalizing correlations among earthquake swarms, ground tilt, and volcanic activity. On 14 May 1922, for example, the level of the lava lake at Halemaumau crater began to drop at a steady rate of about 0.3 m per hour, so that after four days it had fallen 30 m.

An earthquake swarm began on the night of 17 May, and the drop rate accelerated. The summit of Kilauea also began to subside, as indicated by tilting of the Bosch–Omori seismograph.¹⁷

By 26 May the lava lake had drained away entirely. Great cauliflower clouds of dust and steam rose from the crater. After two days, the activity stopped, as did the earthquakes and the summit-wide subsidence. Days later, a new vent opened 10 miles from the summit, and lava began to pour out of the volcano. That sequence of earthquakes, ground movement, and volcanic activity has repeated many times since 1922, each time further clarifying how magma accumulates and moves inside a volcano. (Figure adapted from W. H. Hobbs, *Earthquakes: An Introduction to Seismic Geology*, D. Appleton, New York, 1907, p. 268.)



On the morning of 2 March 1933, the instrument recorded a distant earthquake, which Jaggar recognized as having originated in Japan. He issued a warning of a possible tsunami and stated an estimated arrival time. Piers were cleared of cargo and ships were sent to sea. Within 10 minutes of the expected time, a large wave arrived—the first accurately predicted tsunami.¹³

Jaggar's interest in Alaska never waned. He returned twice in the 1920s, each time with a new amphibious vehicle of his own design. The vehicles, built to climb out of the sea and onto Alaska's rugged shores, were studied by the US military during World War II and used as the basis for beach landing craft.¹⁴

For those and other contributions, a museum at Kilauea was dedicated to Jaggar in 1987, the 75th anniversary of the Hawaiian Volcano Observatory.

Obscurity

Despite his several contributions, Jaggar and his work are little remembered today. (It is said that one MIT professor, while leading a tour of the observatory, was surprised to find that a museum had been dedicated to the man.) I offer two suggestions as to why.

First, as pointed out by science historian Mott Greene, the history of science is dominated by two fields—physics and biology.¹⁵ Historians of geology are especially lacking. Only the early work of Nicolaus Steno, James Hutton, and Charles Lyell is widely known, even though controversial topics, such as the growth of mountains and the nature of Earth's interior, once engaged many natural philosophers.

Jaggar is also partly responsible for his own obscurity. He chose to leave established scientific institutions, and he

published most of his work privately. To him, the highest purpose of a scientist was not to garner acclaim, but to serve humanity.

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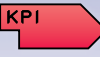
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