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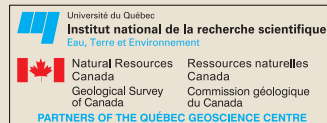
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 Printer: SOLISCO

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## HELL ON EARTH



Hap McSween



The Kawah Ijen caldera and its caustic blue lake of sulfuric acid

Sulfur was known to the alchemists as brimstone. The etymology of brimstone probably derives from the medieval English words *birnen* (to burn) and *ston* (stone). “Fire and brimstone” appears repeatedly in the Bible and Koran, denoting agents of divine wrath—witness the fate of the sinful residents of Sodom and Gemorrah. The Book of Revelations associates brimstone with hell. During the eighteenth century, preachers invoked the sulfurous imagery of hell so effectively that their messages about the final judgment came to be known as fire-and-brimstone sermons. It’s no wonder that sulfur has a bad image.

The properties of sulfur and some of its compounds do little to dispel the notion that this is nasty stuff. Sulfur’s myriad allotropes come in many colors, but the vivid red of hot, molten sulfur is most remembered as the hue of hell in artwork. (Interestingly, the viscosity of liquid sulfur, unlike most substances, increases at high temperatures, due to the formation of polymers. The rubber industry takes advantage of this behavior, using polysulfides to crosslink organic polymers in the vulcanization process.) The pungent stench of sulfur dioxide and hydrogen sulfide announces the presence of sulfur in even small quantities. And sulfuric acid is among the most caustic compounds in chemistry laboratories.

Brimstone has many industrial uses in modern society, and as a consequence, it is mined in many places. No sulfur deposit, though, so epitomizes its hellish image as does that mine at Kawah Ijen, a 2600-meter-tall stratovolcano in western Java, Indonesia. This volcano contains a caldera lake 1 kilometer wide and 200 meters deep. Dip your hand into its 34°C water, and the burning sensation you feel demonstrates that the turquoise-colored liquid is a mixture of sulfuric and hydrochloric acid with pH about 0.5 (similar to car battery acid). This body of water is the largest acid lake in the world. Along the lake’s edges, continuous fumarole activity discharges 4 tons of sulfur gases each day. In 1976, eleven people died from asphyxiation when an enormous bubble of SO<sub>2</sub> erupted unexpectedly from the lake.

Kawah Ijen houses a thriving, if hellish, enterprise—an elemental sulfur mine. Fumarole SO<sub>2</sub> gas is channeled through stone or ceramic pipes, condensing and flowing out at the other end as red molten sulfur. As it solidifies, it transforms into the pure yellow solid. Workers, wearing very little protective clothing or gear to protect themselves from the corrosive gas and searing liquid,

use iron bars to hack the newly hardened sulfur into large chunks. These are then loaded into baskets. Two baskets, together weighing 50 to 90 kilograms, are balanced on bamboo poles and carried on workers’ shoulders up the steep crater walls and then several kilometers down the mountainside to the collection point. Each miner may make two or three such trips each day. The take-home pay for a day of this dangerous, backbreaking labor is about \$5.



Ceramic pipes used to channel and condense sulfur gas into molten sulfur



A worker carries as much as 90 kilograms of sulfur rock down the mountainside.

Nowhere else, to my mind, comes as close to epitomizing hell on Earth, from the perspective of both the natural geologic environment and the human exploitation at this mine. Sulfur mining at Kawah Ijen is featured on a number of websites, and the pictures reprinted here (courtesy of French photographer Fred Relaix) are part of a larger collection that you can view at [www.pbase.com/frelaix/kawah\\_ijen](http://www.pbase.com/frelaix/kawah_ijen). These images provide a fascinating glimpse of a world where brimstone reigns, and perhaps they will sensitize us to the high price paid for a critical natural resource—one that we all use in many forms, without a second thought.

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\* Hap McSween was the principal editor in charge of this issue.