the cooling and a bit of a breeze, the surface waters sink and mix with the deep waters, releasing to the atmosphere what little gas might have accumulated below during the summer.

Since lakes in the tropics experience relatively minor seasonal weather changes compared to those of higher latitudes, it might be presumed that they remain permanently stratified, but limnologists have long known that tropical lakes do turn over, if somewhat less predictably than their temperate counterparts. Lake Bosumtwi in Ghana, another West African nation on the Gulf of Guinea, turns over almost every autumn, says limnologist John Melack of the University of California at Santa Barbara. After a turnover, anoxia prevails from top to bottom, tingeing the air with hydrogen sulfide and driving fish to the surface. The occasional failure of the lake to turn over frustrates the local fishermen, who depend on making easy work of the desperate fish.

The normal change of seasons could have triggered both of the lethal gas bursts, according to a number of limnologists.

Even the most stable lake known in Cameroon, Lake Barombi Mbo, responds dramatically to the changing seasons, according to George Kling of Duke University. Last year he spent 6 months studying 37 of the 50 lakes in Cameroon; 30 of the 37 are set in volcanic craters. In May the stability of Lake Barombi Mbo peaked, but by September it had reached its minimum stability, still considerable but half the value in May. By October, its stability headed back up. This contrary trend, losing stability during the summer instead of gaining it, is driven not so much by increased wind or decreased air temperature, emphasizes Melack, as by the cloudiness of the monsoon season that reduces solar heating.

"It seems like quite a coincidence," says Kling, "that these West African lakes should have minimum stability in August through September and that the two events were on 15 and 21 August. I'm not convinced that it's purely volcanic. It could be purely limnological." Melack, Kilham, and others agree. By their reasoning, Cameroon volcanic lakes are prime candidates for catastrophic turnover. They may not turn over for years or even centuries at a time. The protection from wind afforded by surrounding crater rims and the lakes' relatively great depths—Nyos is more than 200 meters deep but less than 2 kilometers wide—tend to protect them from turning over. The high pressures in the deeper parts of the lakes also allow storage of large amounts of gas.

As long as climatic conditions maintain the stability of a lake, the store of carbon dioxide and other gases could build in the deep, isolated waters. A climate change could then push a lake close to instability and turnover. Climatologist Eugene Rasmusson of the University of Maryland notes that there is a tendency for the tropical belt to be wetter (and its lakes thus cooler and less stable) when the sub-Saharan region is drier than normal. The sub-Sahara just had its worst drought in 150 years. Once driven close to a turnover by long-term climate change, a lake could quickly be pushed over the edge by a summer monsoon. Although a complete turnover takes much longer, the final mixing of anoxic, gas-laden waters to the surface can take less than 2 hours.

The lacustrine explanation has a few hurdles ahead of it. Press accounts of the 1986 event include reports of two explosions, steam, and tremendous heat in streams flowing from the lake. The findings of official investigators, including a party of three earth scientists and three pathologists from the United States, should help clarify these reported phenomena. Chemical analyses of lake water should reveal any injection of volcanic gases by lava. An actual eruption might also leave clues in measurements of lake temperature. As of 2 September, the U.S. scientific team's preliminary evaluation "indicates no evidence of volcanic or seismic activity triggering the event."

Limnologists are hardly adamant about their alternative hypothesis. Most of them readily admit that some role for volcanism cannot be ruled out. A common thought among these researchers is that perhaps there is a mix of volcanic and lake-related factors; much of the gas could be volcanic, seeping into the lake bottom over many years, but the trigger could be lacustrine. Foremost among limnologists' concerns seems to be the respect due their science. After all, they note, the two disasters did spring from lakes, their specialty. Even so, it is the volcanologists who are being quoted in the press and the initial U.S. scientific party included no limnologists, they note. ■ RICHARD A. KERR

Volcanism on Mercury And the Moon, Again

Opinions on the nature of smooth, bright plains on these look-alike bodies have varied in tandem—now such plains on Mercury and some on the moon look volcanic

GIVEN the striking similarity of the heavily cratered surfaces of Mercury and Earth's moon, it is hardly surprising that scientific opinion concerning one of the pair has been mirrored in beliefs about the other. A decade since Mariner 10 took the first and only pictures of Mercury and even longer since Apollo astronauts brought home the last moon rocks, planetary scientists have concluded that early in its history Mercury did indeed spew huge volumes of lava that formed plains. That had been researchers' first thought on seeing the Mariner 10 pictures, but the idea of a volcanic source had been doubted by many since. At the same time, opinion about the nature of some similar plains on the moon has swung back toward pre-Apollo, volcanic explanations.

The first change of mind on the existence and style of volcanism on smallish, rocky bodies came well before anyone saw Mercury as anything more than a nearly featureless, fuzzy ball. Looking at the moon's smooth, relatively bright highland plains, researchers assumed that they were frozen seas of lava that had flooded onto the surface. These plains certainly resembled the larger, darker maria, the plains that form the man (or woman) in the moon. These broad plains were clearly flood basalts that had filled low-lying basins. The highland plains, it seemed, had simply formed from lava of a slightly different composition and thus a lighter color.

But when the Apollo 16 astronauts landed on a highland plain to confirm its volcanic origin, they found nothing volcanic about the landing site. All the rock had been welded together by meteorite impacts from bits of the nonmare crust. Instead of surface flooding by lava, the new, post-Apollo explanation held that the huge impacts that created the maria basins threw out rocky debris that could flow like lava and pond in low spots.

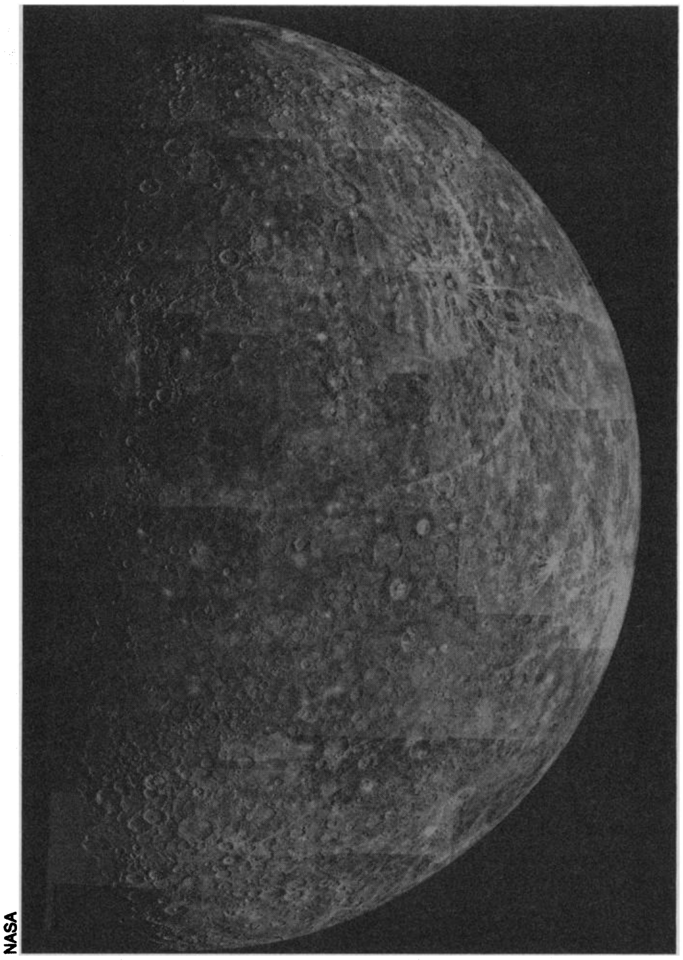
The first reaction of the Mariner 10 imaging team to pictures of smooth plains on Mercury was that they were volcanic, like the moon's maria. But Don Wilhelms of the U.S. Geological Survey (USGS) in Menlo Park, California, pointed out in 1975 that, especially after planetary scientists got burned by the Apollo 16 findings, the moon-Mercury analogy seemed a weak one; perhaps Mercury has no volcanic features. A better hypothesis might be that the great impact crater called Caloris, around which most of the smooth plains seemed to be arranged, tossed out plains-forming debris flows.

There the debate remained until recently when new, Earth-based observations of the moon and reanalysis of old images of Mercury forced a return toward volcanism. Paul Spudis of the USGS in Flagstaff has produced a new map of the geological features in Mariner 10 images of Mercury that draws on knowledge of both Mercury and the moon accumulated during the past decade. On Spudis's map, instead of the smooth plains clustering around Caloris, they cover 40% of the area imaged by Mariner 10. The Caloris impact would not likely have created any type of feature that is that widespread, Spudis reasons. Using Earth-based radar, Pamela Clark and Raymond Jurgens of the Jet Propulsion Laboratory and Martha Leake of Valdosta State College have mapped almost a third of the planet, all within the equatorial region and much of it well outside the reach of the Mariner 10 camera. Ten to 20% of the area mapped by radar appears to be smooth plains, says Clark.

Spudis has also shown that the smooth plains did not form at the time of the Caloris impact and its ejection of debris. Any planetary surface accumulates more impact craters as it ages, as long as the surface is not renewed by resurfacing. By comparing crater counts, Spudis found that Caloris and its ejecta are distinctly older than the smooth plains surrounding them. The Caloris impact, apparently the last giant impact in a bombardment by debris left from the formation of the solar system, might have produced fractures in the crust that later allowed magma to rise to the surface, but it could not have directly created the plains as ejecta, according to this dating.

Smooth plains on a battered Mercury

Unlike the dark maria plains of the moon, Mercury's plains contrast little with surrounding rock. At the extreme left-center of this Mariner 10 image, a semicircle of ejecta marks the edge of the Caloris basin created by a large impact. Beyond the ejecta lie smooth plains of lava.



NASA

Meanwhile, some lunar plains cited as analogs of the plains of Mercury were looking more volcanic too. Peter Schultz of Brown University and Spudis noted that some craters on these lunar plains had apparently punched through to underlying dark basalt and thrown it outward to form a dark halo. The dark material, they suggested, could be mare basalt buried by half a kilometer or more of brighter highlands rock tossed over it by one of the large impacts that created a basin later filled by mare basalt. The formation of a mare basin might thus bury any chemical signs of earlier flood volcanism. In that case, more than 15% of dark lunar basalts are disguised as light-colored highland plains, say Schultz and Spudis. Jeffrey Bell and Ray Hawke of the University of Hawaii have since shown through infrared spectroscopic studies that the dark halos do have the same spectroscopic signature as mare basalt.

Another bright, smooth plain on the moon, the Apennine Bench Formation within the Imbrium basin, also appears to have had a volcanic origin, according to both Spudis and Bell. This plain is near the Apollo 15 site where astronauts found trace element–rich basalts that had arrived there as impact ejecta. The bright plain nearby, presumably a possible source of these basalts, also shows this odd composition in the chemical determinations obtained from lunar orbit. Thus, the bright plain may be volcanic but brighter as a result of its chemical composition.

Mercury has been awarded status as a volcanic planet, in part because of analogies with the moon, but, as one planetary scientist warns, "Mercury is not the moon. The smooth plains of Mercury are not lunar maria." A major difference is timing. The smooth plains of Mercury erupted near the tail end of the bombardment; global compression of the crust soon cut off the conduits carrying magma to the surface. On the other hand, the maria lavas filled impact basins, formed during the bombardment, more than half a billion years after its end. Robert Strom of the University of Arizona argues that the intercrater plains of Mercury erupted even earlier during the bombardment; on the moon only fragments of such early mare volcanism survived, if it occurred at all. Analogies can be useful, but they have their limits. ■ RICHARD A. KERR