the inner Zagros thrust belt; the interpretation farther north-east is still geologically obscure.

Dietz and Sproll do not say where they have taken the contact of Gondwana and Laurasia farther east between the Persian Gulf and West Pakistan. There is clearly insufficient evidence to identify a northern margin to Gondwana in this area now, because it has either foundered beneath the sea or suffered a Cary spenochasm. But in Upper Cretaceous times we do know that the Zagros eugeosynclinal belt bent around into Oman to run south and south-east towards the Arabian Sea. It is logical to assume on geological grounds that this orogenic belt was connected in some way with the belt of Upper Cretaceous folding which runs north from Karachi: that this belt connects under the Arabian Sea with the Murray Ridge is unlikely to be pure coincidence.

The necessary change in the position of the Middle Eastern Gondwana and Laurasia contact adds about 700,000 km² to the former supercontinent at the expense of the latter, confirming that the apparent close similarity of the areas of the two supercontinents measured by Dietz and Sproll must be fortuitous, as they acknowledge.

N. L. FALCON

British Petroleum,
B.P. House,
Ropemaker Street,
London.

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Particles in Volcanic Fume

THE relatively quiet outpouring of lava during many volcanic eruptions, such as those in Hawaii and Iceland, is accompanied by the emission of large quantities of fume. Almost nothing is known about the particles in such fume although numerous studies have been made of the gaseous composition^{1,2}. At times in the Earth's history, for example during the eruptions that produced the Columbia Plateau in the United States, tremendous amounts of such particles must have been emitted into the atmosphere.

During 1965, Halemaumau (the main vent of Kilauea volcano in Hawaii) emitted large amounts of fume (Fig. 1). This is unusual for Kilauea except during an actual eruption and suggests that magma was very close to the surface. The odour of the fume was similar to that of sulphur dioxide. Scattered light from the fume in the crater was bluish, but as the fume rose it became white, suggesting that the particles were absorbing water vapour and enlarging as they rose.

Samples of the particles in this fume were collected in August, September and December of 1965. Both a 'Unico' multistage impactor and a filter composed of polystyrene fibres less than a micron in diameter were used. Fume was drawn through the impactor and filter with a 'Gelman' battery driven pump or a 'Uni-Jet' air sampler. Particles collected at the crater's edge with the impactor were entirely on the third and fourth stages, which at the flow-rates used collected particles which had mass median diameters of about 5 μ and 3 μ respectively, assuming that the particles had a density of 1 g/cm³. The particles were undoubtedly much smaller when first

Fig. 1. The appearance of Halemaumau in September 1965. The fuming crater is about one half mile across.

emitted from the vents. Almost no particles were collected on the impactor slides away from the crater.

Microscope examination of the impactor samples showed that they were agglomerated droplets that remained liquid at a relative humidity of 30 per cent, and consisted of supersaturated aqueous solutions of a crystalline solid. Tests with Nessler's reagent and with an aqueous solution of barium chloride showed that the solute contained ammonium and sulphate ions, respectively. The crystalline solute was tinged yellow but probably did not contain elemental sulphur since it was soluble in water and insoluble in carbon disulphide. Possibly some ferric ions were present. Testing with acidified aqueous silver nitrate solution failed to reveal the presence of any chlorine ions. The droplets absorbed water and grew in size when the impactor slide was placed on a moist chamber on the microscope stage.

Using the electron diffraction feature of an electron microscope, electron diffraction patterns were obtained for about thirty crystals of the solute from the impactor slides. All corresponded to ammonium sulphate; no sodium chloride or sulphur particles were found.

Particles collected on the fibre filter were examined with the electron microscope using a replica technique. Many of the particles (which, of course, were evaporated droplets) were in the size range 1–10 μ diameter. There were also large numbers of smaller particles.

Ammonia has not previously been reported in the fume from Kilauea although it is known to be emitted by other volcanoes^{3,4}. Although these samples were handled with great care, the possibility that they were contaminated with atmospheric ammonia cannot be dismissed. Additional investigations of this kind, especially of the fume above molten lava, are needed to establish whether ammonium sulphate is indeed an important component of the fume of erupting volcanoes. If so, enormous amounts of ammonium sulphate must at times be emitted into the atmosphere by volcanic eruptions.

R. D. CADLE
A. F. WARTBURG
E. R. FRANK
J. P. LODGE, JUN.

National Center for Atmospheric Research,
Boulder,
Colorado.

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