composition like that of carbonaceous chondrites. On the basis of the abundances of lead, bismuth and thallium, Anders estimates that the amount of this chondritic material on the Moon is equivalent to a 9 metre thick layer which would contain 370 g cm^{-2} of water corresponding to a 3.7 metre deep covering if all of it were liquid. This relatively small amount of water is an overestimate, however, Anders says, because it fails to take into account the energy released by the impacting material in the final stages of accretion. This would be enough to vaporize virtually all of the water that it contained and would also account for the absence of the volatile element sulphur in the soil collected by Apollo 11.

Anders says therefore that the case for substantial amounts of water on the Moon seems to be weak, thus begging the question of how the Earth comes to be so wet. There are several possibilities—the Moon may have accreted closer to the Sun, for example—but Anders gives weight to the view that the dynamics of accretion processes were different.

With the Apollo 15 expedition therefore unlikely to pick up evidence for a lunar hydrosphere from Hadley rille next summer, the aqueous explanation of the sinuous rilles is becoming unfashionable. In the September issue of the *Geological Society of America Bulletin*, S. A. Schumm of Colorado State University extends the fluidization hypothesis of lunar features to the rilles, explaining how the outgassing from the lunar interior that has been put forward to account for flat-floored craters may also have created other shapes (81, 2539; 1970). Schumm has set up a fluidized bed in which a layer of sand a few centimetres thick represents the lunar regolith and compressed air is blown through a pattern of holes beneath the bed to produce fluidization. Using linear and sinuous arrays of holes, Schumm can create structures resembling crater chains and rilles in the artificial regolith.

ARCHAEOLOGY

Sources of Obsidian

from our Geomagnetism Correspondent

THE philosophical and methodological parallels between geology and archaeology are well known; and recently both disciplines have benefited from the wider utilization of techniques once reserved for the physical sciences. The direct application of geological exploration to archaeological problems is still comparatively rare, however, probably because contact between students of the two disciplines is a matter of chance rather than a systematic attempt to discover and cooperate on common ground. How Patton and Miller (*Science*, 169, 760; 1970) came to see their geological investigations as a solution to a problem in Alaskan archaeology will perhaps never be known, but archaeologists should be pleased that the connexion was made.

The archaeological problem is simply stated. In recent years artefacts and chippings of obsidian have been found in conjunction with chert and slate artefacts at several archaeological sites in Alaska, notably the excavations at Cape Denbigh and Onion Portage (see map). But whereas chert and slate are widely distributed in north-western Alaska, no one has ever discovered the source of the obsidian. As a result,

archaeologists have had to rely on unproven hypotheses which envisage the transport of obsidian from as far away as the Aleutian Islands. Giddings (*Arctic Anthropol.*, 1, 6; 1962), for example, even related the variations in obsidian abundance at various archaeological levels at Onion Portage to "the ebb and flow of coastal-oriented and inland-oriented cultures along the Kobuk valley". Clearly, the source of the obsidian is an important factor in the elucidation of cultural ties and trading routes in ancient Alaska.

Patton and Miller have put an end to speculation by their discovery of obsidian deposits near Hughes, Alaska, only a hundred miles or so from the Onion Portage site. The mere proximity of the source to the ancient settlements does not, of course, prove a physical connexion; but closer comparison of the excavated and indigenous obsidians goes a long way to doing so. On the descriptive level, most examples of the two obsidians compare well in colour, opacity and the absence of hydration and devitrification. And, quantitatively, use has been made of recent techniques for matching archaeological samples with bedrock deposits by chemical composition. Of particular interest in this connexion is the ratio of sodium to manganese, both elements which vary widely between obsidian flows. The ratios of sodium to manganese of the Onion Portage and Hughes obsidians are similar. The scientific and circumstantial evidence for the connexion is thus strong.

Unfortunately, Patton and Miller were unable to carry out a systematic search for evidence of ancient "mining" of the bedrock deposits. Even so, several artificially chipped obsidian flakes were found among the natural residual fragments. Furthermore, chipped fragments found on nearby hillsides and ridge tops could only have been carried there by human agency. The only question now is whether or not the Hughes site was the only source of obsidian for the ancient Alaskan communities. No further sources have been discovered, but geological associations are favourable along much of the Koyukuk and lower Yukon Rivers.