MOON

First Impressions

By the time the lunar samples brought back by Apollo 11 have been wrung dry of scientific information, the second American expedition to the Moon will have already been mounted. Almost certainly, the next landing will be at one of the two sites in the eastern hemisphere which have been chosen as smooth enough for a landing—both sites are near the equator in Oceanus Procellarum. This way by the end of the year NASA will have recovered samples of typical mare regions in both the eastern and western hemispheres of the visible face of the Moon. What the Apollo 12 astronauts—Charles Conrad and Alan Bean on the surface and Richard Gordon in the command module—will be instructed to look out for will depend on the first-hand descriptions of the surface radioed by Armstrong and Aldrin on Monday morning (BST) and on preliminary analyses of the samples. Already the astronauts' impressions of the surface material are adding to what has been inferred from the crude chemical and mechanical analyses carried out by the Surveyor soft-landers. The experimenters fortunate enough to be on NASA's distribution list now have a better idea of what to expect.

Armstrong's first description that "the surface appears to be very finely grained as you get close to it, it's almost like a powder" matches the Surveyor results which point to a matrix made up of finely divided particles sometimes aggregated in lumps. That the surface took a clear imprint of treads on Armstrong's boots was expected from the impressions left by a pattern inscribed to a depth of 50–70 microns on the Surveyor footpads, which implies that much of the moondust must be finer than 60 microns. The cloud of dust raised by the descending lunar module at a height of 70 feet must have consisted of this fine material. A few minutes later Armstrong recorded that "it's a very soft surface, but here and there where I plug in the contingency sample collector, I run into a very hard surface, but it appears to be very cohesive material of the same sort". Some of the hard rocks collected in the contingency sample had what seemed to be vesicles in the surface, and one seemed to have some sort of phenocryst—a prominent embedded crystal.

Later Aldrin found some purple rocks containing what he guessed to be biotite, a mica which can be green, brown or black found in terrestrial granites and in the lavas of Vesuvius. Armstrong described some boulders as looking like basalt and having probably 2 per cent white minerals in them. The rock seemed to be peppered with tiny impact craters. At one stage one of the astronauts described the soil as a greyish cocoa colour.

The mechanical properties of the soil are much as the Surveyor data predicted. Aldrin said: "I could suggest exactly what the Surveyor pictures showed when they pushed away a little bit. You get a force transmitted through the upper surface of the soil and about five or six inches of bay breaks loose and moves as if it were caked on the surface when, in fact, it really isn't." Armstrong noticed that the soil is very cohesive and will retain a slope of probably 70°. This seems to have been the kind of phenomenon with which powder metallurgists are familiar—rough powders more easily transfer stresses to each other.

What seems to have been surprising was the lack of damage to the surface caused by the impact of the lunar module and the blast of its engine. According to Armstrong's preliminary inspection, "The descent engine did not leave a crater of any size. . . . I can see some evidence of rays emanating from the descent engine, but very insignificant amounts."

LUNAR SURFACE

What is the Surface Like ?

First reactions by British scientists who are to receive lunar samples centred on the handful of mineralogical references in the astronauts' comments, and on their descriptions of the consistency of the surface material.

Aldrin's mention of biotite caused most comment. Dr N. J. Snelling of the Institute of Geological Sciences, where the mineralogy and distribution of radioactive materials in the samples are to be investigated, found the reference to biotite surprising. The surface material could be generally basaltic, as the Surveyor soft-landers seemed to suggest (although a reconsideration of the Surveyor results has laid seeds of doubt about this interpretation), or it could be meteoritic debris; in neither case is biotite expected. If it is not a case of misidentification, the biotite almost certainly indicates volcanic material which has undergone more chemical processes than one might have expected on the Moon. On the other hand, Dr S. W. Richardson of the Grant Institute of Geology, University of Edinburgh, where the crystal structure in the samples is to be investigated for hints of the conditions under which crystallization took place, doubted that Aldrin was close enough to the rock he was describing to identify biotite. But he pointed out that the mention of phenocrysts suggested a rock which had crystallized at moderate or shallow depths. If biotite was indeed present, then the rocks must be highly differentiated and there must have been a high partial pressure of water. The white mineral which Armstrong mentioned in a rock which seemed to be basalt is probably plagioclase feldspar. Professor J. Zussman of the Department of Geology at Manchester University agreed that the identification of biotite is doubtful considering the conditions under which the astronauts were working. Many other minerals glint in the same way as biotite.

The vesicular appearance of the rocks was interpreted by Professor Zussman and by Dr Snelling as indicating a lava extruded in vacuum conditions, so that gas bubbles leave the rock looking like a sponge. Terrestrial lava flows have the same appearance. An alternative possibility is that the vesicles are tiny impact craters.

Professor G. M. Brown of the Department of Geology, Durham University, where a petrological examination of samples is to be undertaken, thought that the astronauts posed as many problems as they answered. Biotite is difficult to account for because of its water content, and there is the problem of explaining the extremely finely divided nature of the surface soil. The references to the slipperiness are also hard to

MARS

Mariners reach Mars

THESE are busy weeks for steerable radio telescopes. Parkes (New South Wales) and Goldstone (California) have been tracking Apollo 11, Jodrell Bank has been concentrating on Luna 15 and, next week and the week after, Goldstone will be following the Mars probes which are reaching their destination after a journey of five months and something like 200 million miles.

Neither probe will be able to detect the presence of life, but the hope is that they will determine whether the martian environment is suitable for life to develop. And the question of martian canals should be settled once and for all by the television pictures which are to be radioed back.

Both Mariners were launched from Cape Kennedy, Mariner 6 on February 24 and Mariner 7 on March 27, and they are to make close approaches to Mars on July 30 (10.18 p.m. PDT) and August 4 (10.00 p.m. PDT) respectively. Each Mariner is to look at a different part of the planet—Mariner 6 is to photograph the equator and Mariner 7 part of the southern hemisphere and the polar cap. The two probes are the second stage in NASA's exploration of Mars. They follow Mariner 4 which in 1964–65 photographed Mars with a best resolution of two miles (compared with 100 miles for terrestrial telescopes). The next step is scheduled for 1971, when it is planned to place two spacecraft in orbit for two months, followed by two soft landings—the Viking project—in 1973.

As well as the television cameras, next week's Mariners have a complement of instruments which makes them the most sophisticated planetary spacecraft so far. Radiometers will produce infrared maps to compare with the television pictures, and should enable people to decide whether the ice caps are water or solid carbon dioxide. The constituents of the upper atmosphere are to be analysed by an ultraviolet spectrometer, and those of the lower atmosphere and surface by an infrared spectrometer. Chemicals such as water, carbon dioxide, methane, ethylene and acetylene can be detected, in some cases in concentrations down to two parts per million. Atmospheric pressures and densities will be measured from the effect on the telemetry as the Mariners swing behind Mars, when the signals will have to pass through the atmosphere. As a bonus, radio tracking of the spacecraft orbits throughout their flights should improve the values of some astronomical parameters—the mass of Mars, the mass ratio of the Earth and the Moon and the distance from the Earth to Mars when the Mariners arrive.

If all goes well, the television pictures will have a best resolution of 900 feet, and colour filters which can swing in front of the lenses will allow colour pictures to be built up. Each Mariner will begin taking pictures a few days before the closest approach, and a complete coverage of the planet except for the pole caps should be achieved as the planet rotates. (A martian day is 24·6 hours.) Altogether, 143 approach pictures are to be taken if communications with the spacecraft are up to scratch. Otherwise, a more conservative sequence of eight approach pictures by each Mariner is planned. If all goes well, the first pictures should be appearing on the monitors at Goldstone at 18.35 (PDT) on July 29. One of the martian moons, Phobos, could appear on the approach sequence. Close-ups of the surface will begin to be taken 15 minutes before the time of closest approach, with one picture every 42 seconds. Every seventh picture element will be transmitted back to Earth in real time, and a complete picture will be replayed from tapes after the encounter. Each Mariner is programmed to take twelve high resolution and twelve medium resolution pictures during the close approach.

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understand. Professor Brown thought the indications were that the rocks are lava and that the fine dust is meteoritic.

Two points particularly attracted the attention of Professor S. Tolansky of the Royal Holloway College, University of London, who is to prospect in the samples for diamonds. One was the way the fine dust stuck to the astronauts' boots, which Professor Tolansky attributed to electrostatic charges on the dust due to bombardment by the solar wind. The second point has to do with Professor Tolansky's interest in tektites, and a remark which he heard from one of the astronauts that there was something glassy-looking. Professor Tolansky believes this was either a tektite, or a splash of glassy material generated by the heat of an impacting object.

The team led by Dr J. E. Geake of the Institute of Science and Technology at Manchester University, which will be investigating optical emissions and the optical polarization of specimens, is interested in the dust layer. Mr G. Walker was gratified that the lunar surface was lighter than the material immediately beneath. This seems to have been caused by radiation damage of the topmost soil. One problem in the past has been that laboratory experiments with protons suggest that most particles darken under radiation, but it now looks as if vacuum pump oil was getting into the equipment and darkening the specimens. He added that the colour of the lunar surface seems to match that of the powdered basalt which the Manchester team has had in its equipment. Dr Geake commented that the behaviour of the dust bears out the results of experiments by Dr Salisbury at the Air Force Cambridge Laboratories. There it was found that if almost any dust is pumped down to 10^{-10} torr to represent lunar conditions, an adsorbed layer of air molecules which remains in softer vacuums is stripped off. Van der Waals forces then come into play between the grains and the dust behaves like a wet soil. In the Air Force Cambridge experiments, dust sifted through fine wires built up on the wires like wet snow.

Professor A. W. Bishop of Imperial College, London, who is not involved with the analysis of samples, commented on the Moonwalk from the point of view of soil mechanics, especially the way the lunar soil behaves as if it had a caked surface. Electrostatic forces giving apparent cohesion is one explanation. More likely is that the dust is extremely rough, something like pulverized coke. This is expected to be the case on the Moon where there is no weathering to produce the smooth round particles which are usually encountered on the Earth. The particles then lock together and transmit stresses better than terrestrial dusts.