GENERAL NOTES

Absorption of Water on the Moon and the Planets[1]

By A. Véronnet

It seems well established that the surface of the Moon is now entirely destitute of water and that the process of erosion has never been very active in the past.[2]

On the other hand, we know that the rocks forming the crust of the Earth have a capacity for absorption as a result of cooling. Calculation shows that, the mass of the Moon being less and its surface relatively greater, its seas must have been much less important than those of the Earth, and that its crust has been able to absorb all the surface water. For this conclusion it is sufficient to admit that the constitution of the Moon is analogous to that of the Earth and that it is composed of about the same elements.

It has been shown by A. Gautier[3] that 1 kilogram of granite heated from 15° to 250° gives out 2.3 grams of water, and 7.3 grams from 250° to 1000°, or 9.6 in all. This number should be multiplied by 2 for porphyry and by 2.5 for other rocks. It measures the quantity of water which the rocks have absorbed thru the process of cooling from their melting point.

Lord Kelvin, on the other hand, has determined the law of decrease of surface temperature of a celestial body under conditions which may be regarded as sufficiently close to reality for a first approximation. Since rocks melt at about 900°, the initial temperature of the crust must have reached at least this minimum. On this hypothesis I have calculated the temperature for various depths. Representing the surface temperature by zero and allowing a surface increase of 1° per 33 meters, or 30° per kilometer, the following values are obtained:

Kilometers	0	10	20	30	40	50	60	70	80
Temperature	0	292.7	539.8	713.4	817.1	868.4	889.6	896.7	899.3

The density of the crust may be considered as 2.5. Then, calculating for various depths, the quantity of water absorbed as a result of this fall in temperature, we find, in the case of granite, a quantity of 43 liters per square centimeter of surface, which corresponds to a layer of water 430 meters in depth.

[1]Translation by Elizabeth Connor of a note in *Comptes Rendus*, **165**, 629, 1917.
[2]Puiseux, P., *Bull. de la Soc. astron. de France*, **30**, 113, 1916.
[3]*Bull. Soc. chim. de France*, **25**, pages 231 and 402.

Assuming instead of 900° an initial temperature that is certainly sufficiently high, 3000° for example, the increase in temperature obviously becomes linear up to 900°, that is, up to 30 kilometers. We thus obtain 34 liters per square centimeter and a depth of water of 340 meters.

The two limits of the depth of the absorbed water are indeed very close, 340 and 430 meters. This depth depends very little on the hypothetical initial temperature. As the absorption would be 100 meters for the first four kilometers in the granite and the rate of absorption by the geological sedimentary layers has certainly been much greater than this, tho more difficult to evaluate, we may consider an absorption of 400 meters as a minimum. Finally, we will have, for the depth of water absorbed by the cooling of the Earth's crust, $h = 400\ \alpha$, in which α is the mean coefficient of absorption per kilogram of the rocks of the crust. It lies between 1 and 2.5, which gives a depth of water absorbed of something between 400 and 1000 meters.

According to Martonne (*Géographie physique*) the mean depth of the seas and oceans is about 3650 meters and they occupy 0.725 of the surface of the sphere, which would give a uniform layer of about 2700 meters. The initial layer of water, before any absorption, would have been from 3100 to 3700 meters. It is useless to take into account the water that enters into the constitution of the rocks, which depends on the mass and not on the surface.

Let us now consider the Moon or some other planet. Let us first suppose that the elements are the same as those of the Earth and in the same proportions. The quantity of water present will be proportional to the mass. The depth of the primitive layer will be proportional to the mass divided by the surface, that is, to the product of the radius by the density, or again, to the surface gravity of the body. On the other hand, the depth of the absorbed layer will be almost the same as for the Earth, the time and the decrease in temperature being almost the same. Designating by γ the surface gravity of the celestial body, the mean depth of the remaining layer of water will be given, according to the numbers obtained above, by the formula

$$H = (2700 + 400\ \alpha)\ \gamma - 400\ \alpha.$$

For the Moon we find that there is no more water if $\alpha = 1.3$, a value lying between the limits of absorption of the rocks of the crust, 1 and 2.5. It is then quite possible and probable that the rocks of the crust have absorbed all the water of our satellite, by slow diffusion, as the cooling has progressed.

For *Venus* the mass is nearly that of the Earth. The depth of the water originally, and at present, would be about the same as for the Earth, 2300 meters. The surface conditions would be the same, except for the temperature which, on the basis of the temperature of the Sun and its distance from *Venus*, would reach 90° at the equator and 70° at a latitude of 45°. These conditions were those of the secondary (Mesozoic) period on our own sphere, when the Sun was somewhat larger and hotter. *Venus* should now be surrounded by a thick layer of vapor, which explains the great reflecting power of her surface (0.88), the same as that of terrestrial clouds.

For *Mars* the depth of water remaining would lie between 230 and 630 meters, according to the limits of α, with a maximum of only 900 meters at the beginning. Its seas have always been much smaller in extent than those of the Earth. This point is particularly helpful in explaining the small percentage of water vapor in its atmosphere, the more so as its temperature at the equator has probably already fallen to about 20° above zero, a condition which will be reached by the Earth only after some millions of years.

Finally, for *Mercury* the mean depth of the water would lie between 500 and 860 meters, but its temperature would be close to 220° at the equator and 190° at a latitude of 45°. As the density of *Mercury* is much greater than that of the Earth, the proportion of light elements should be less. Supposing the depth to be 400 meters, the pressure of this layer would be only about 16 kilograms per square centimeter. The water being completely vaporized at this high temperature, there would as yet be none condensed on the surface of *Mercury* and the planet would not yet have an envelope of clouds like *Venus*. This would explain the limited reflecting power, 0.16. There the astronomical period of formation has not yet ended; the geological periods have not commenced.

The quantity of initial water has been taken as proportional to the mass. But the density of the Moon and of *Mars* is less than that of the Earth, being 0.61 and 0.69, respectively. One may consider the light elements, and water in particular, as present in greater abundance, and proportional to the volume. Then for the depth of the water the same formula is obtained as above, but in it γ is replaced by the radius. It is necessary then, in order that the absorption of the water be complete on the Moon, that $a = 2.5$ —a value within practical limits. On this hypothesis the depth of water on *Mars* would lie between 1000 and 1300 meters.

Only two prizes in astronomy were awarded by the French Academy of Sciences for the year 1917, the Prix Lalande to Mr. Robert Jonckheere, and the Prix Valz to Mr. Alexandre Schaumasse. The award to Mr. Jonckheere was made for his Catalog and Measures of Double Stars discovered visually from 1905 to 1916, which was briefly reviewed in an earlier number of these PUBLICATIONS. This Catalog contains all of Mr. Jonckheere's own discoveries, which number 1319. It was recommended that the prize in this instance be increased from the usual amount to 1000 fr. The award to Mr. Schaumasse is for his discovery of Comet 1917 *b*, while suffering from severe wounds received in military service.