examples in the Guitarrero I collection. In view of the stratigraphic position and early radiocarbon date of the Guitarrero I industry, many will choose to ignore the isolated projectile point, accept the possibility of some disturbance, and assign the complex to Krieger's pre-projectile point stage. Sample GX 1859 yields the earliest charcoal date on human activity yet reported from South America, although MacNeish's more problematic bone determination of 12,200 B.C., from Ayacucho, precedes it by 1,590 years (*4*).

The possibility of intrusions from above during later occupations is especially critical in the case of a human mandible found in association with the Guitarrero I complex in the lowest stratum of the cave. If this association is genuine, it is the earliest known occurrence of human skeletal remains in South America—and among the best demonstrations of early man and his works in the entire New World.

The likelihood of an intrusive burial or similar disturbance is minimal. In the excavation square from which the mandible came, ten levels of unbroken and apparently uncontaminated preceramic deposits lay directly above (Fig. 2). All sediments from these levels were sieved through 3 by 3 (about 1/4 inch or 2/3 cm) or smaller mesh screens, and no other human bone was found. Eight of the ten superimposed levels are subdivisions of the stratigraphically and typologically distinct Guitarrero II preceramic complex, which dates from about 8,500 to 5,700 B.C. on the strength of the four charcoal dates cited. Of the two dated samples on the Guitarrero I stratum, sample GX 1859 (10,610 B.C.) from 15 cm below the mandible, was most closely associated with the skeletal remains and is in best agreement with the four very consistent assays on the stratum above. Thus, the mandible, a premolar tooth from a different individual, and a phalanx may be assigned an age of about 12,000 radiocarbon years.

In comparison to the excellent condition of late intrusive burials in other parts of the site, this small sample of skeletal remains is rather poorly preserved and can be instantly distinguished from the later bones. The left ramus of the mandible is missing except for the gonion, and only the gonial portion of the right ramus is present. The following eight teeth are in place: right first and second premolars, right first and second molars, left lateral incisor, left first premolar (fragmentary), left second premolar, and left first molar. The isolated right first premolar, from another individual, shows little wear on the occlusal surface, which suggests that it belonged to a young subject. The phalanx is adult and complete except for the head at the distal end.

The mandible is small and apparently female. A general rugosity and strong pterygoid ridging are salient characteristics. There is considerable muscularity of the mylo-hyoid ridge and pronounced genial tubercles; however, the chin is median in form and the ramus-corpus angle is very obtuse. All teeth have erupted, and various features suggest an age of possibly 30 to 40 years at the time of death. Senile changes can be seen in the reduced height of the corpus at the level of the molars and in the moderate osteoporosis around the alveoli. Occlusal attrition of the teeth is moderately low and dentine lakes are small. The third molars had erupted but were lost before death.

The dental health of this individual was good. If there were abscesses of the third molars, the absorption continued to the point of normal correction at a period of several months to a year. There is no evidence of caries, and the rather small teeth are not crowded, with general dental anomalies being absent.

The pattern of occlusal wear is rather interesting, especially the low degree of attrition of the molar teeth. This is in sharp contrast to the left lateral incisor, which is a peg root without enamel. Although it is risky to infer much from a single mandible with an incomplete set of teeth, it may be that the anterior portion of the mouth was used for certain activities other than the mastication of food. Molars and premolars show the direction of wear to be buccal. The low degree of molar wear, even on the first molars, suggests a diet of soft foods that were free from grainy and foreign elements. Perhaps this corresponds to the stress on hunting and meat eating, which has frequently been proposed for the first Americans.

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Water on the Moon?

Abstract. *If the planets formed at falling temperatures with volatile substances accreting last, the low abundance of lead, bismuth, indium, and thallium in lunar rocks implies an initial water content of no more than 370 grams per square centimeter, and probably much less. The depletion of volatile substances might be expected a priori if the moon accreted as an original satellite of the earth.*

Did the moon ever contain large amounts of water? The Apollo 11 and 12 rocks certainly show no water, no hydrated silicates, and no signs of aqueous alteration (*1*). And the present escape time of water molecules from the moon is very short, less than 1 year (*2*). Nonetheless, this evidence does not preclude the possibility that the moon once had substantial amounts of water. Various surface features, such as sinuous rills, mare fillings, ghost craters, and domes have been attributed to the effects of an early hydrosphere (*3*), and the survival of some primordial water in permanently shadowed areas (*4*) or permafrost layers (*5*) has been proposed.

Actually, there exists a way of estimating the original water content of the moon. It depends on a model for the accretion of the meteorites and terrestrial planets, which, although not the last word on the subject, is consistent with all available evidence. When the abundance pattern in ordinary chondrites and the earth is compared with the condensation sequence of the elements from the solar nebula, it turns out that all elements with condensation temperatures below 600°K (Pb, Bi, Tl, In) are depleted by factors of 10^{-2} to 10^{-3} (*6, 7*). For the meteorites, the degree of depletion suggests accretion temperatures of 460° to 560°K (*7*). Such temperatures have, in fact, been predicted for the solar nebula on independent grounds (*8*). For the earth, a "mean" temperature of the same order can be inferred, but it is probably fictitious. Very likely, the accretion occurred at falling temperatures, highly volatile compounds having been acquired mainly in the terminal stages of accretion. Arguments in favor of such inhomogeneous accretion have recently been presented by Anders (*9*) and by Turekian and Clark (*10*).

In a cooling solar nebula, water would begin to condense at ~350°K, in the form of hydrated silicates similar to those found in carbonaceous chondrites (*6, 7*). An additional amount of hydrogen, ultimately converted to water, would condense in the form of complex organic compounds (*9, 11*). The condensation temperature of this organic material cannot be reliably calculated from thermodynamics, but data on meteorites suggest a condensation temperature of $\leqslant$550°K. Thus a planet's C, H_2O, Pb, Bi, Tl, and In may have been acquired as a veneer of material of carbonaceous chondrite composition, in the form of dust or planetesimals up to kilometers in size.

For the earth about 10^{-3} earth masses of such material would be required in order to account for the water content (*9*). For the moon a firm figure cannot yet be given, but if the 100-fold depletion of Pb, Bi, and Tl in Apollo 11 and 12 basalts relative to terrestrial basalts (*12*) is assumed to be typical of the moon as a whole, some 10^{-5} of the lunar masses of carbonaceous chondrite-like material is required. This is equivalent to a layer 9 m thick. For comparison, the projectiles that formed the highland craters were equivalent to a 50-m layer (*13*). Chemical studies of highland rocks may show whether the volatile substances were accreted before or after differentiation of the highlands, and before or after formation of the highland craters.

A 9-m layer of carbonaceous chondrite material is equivalent to about 40 g/cm² of H or 370 g/cm² of H_2O. On this basis the moon could never have had more water than the equivalent of a layer 3.7 m thick. In reality the amount would be even less. At the minimum impact velocity (lunar escape velocity, 2.4 km/sec) the energy release is sufficient to vaporize the projectile. Although some of the energy is imparted to the target, it seems certain that much of the projectile's water is lost. This appears to be the case in recent meteorite impacts on the moon. Studies of trace elements have shown that Apollo 11 soil and breccias contain about 1.9 percent meteoritic material of carbonaceous chondrite composition (*12*). Yet the sulfur and water associated with this material were not found. Apparently sulfur and water are too volatile to be retained in such impacts. Although impact velocities during the moon's formation were lower than in recent times, it still seems likely that much of the water was lost during impact. Thus the case for substantial amounts of water on the moon seems to be rather weak, as already noted by O'Keefe on independent grounds (*14*).

One may ask why the moon contains so much less Pb, Bi, Tl, In, and H_2O than the earth. Several authors have attributed this difference to large-scale volatilization events that vaporized silicates and, of course, all substances of greater volatility (*15*). It has also been proposed that the moon accreted closer to the sun, where temperatures were higher. But it seems doubtful that a sufficiently steep temperature gradient could have been maintained in the presence of radiation-absorbing dust. An alternative explanation may be found in the dynamics of the accretion process. There are factors that greatly favor a planet over a satellite. Ganapathy *et al.* (*12*) have noted that a satellite, because of its orbital motion around a planet, would have a higher encounter velocity and hence a smaller capture cross section for dust in circular heliocentric orbits. At 5 to 10 earth radii, this effect might depress the moon's terminal accretion rate per unit mass by a factor of 10^{-2}, *if the moon were earthbound.* For a *sunbound* moon, the accretion rate would be depressed, at most, to 0.28.

In a rigorous treatment of this problem, which has not yet been given, one would have to consider the damping effects of gas (important for objects of $\leqslant$10-m diameter at a gas pressure of 10^{-3} atm), the differential motion of earth and gas due to the noncircularity of the earth's orbit, and the gravitational focusing and acceleration of larger planetesimals. Some of these effects would counteract the decrease in capture cross section noted by Ganapathy *et al.* Nonetheless, the fact that the moon has only 1/81 the mass of the earth suggests that its *average* accretion rate was lower. Perhaps the difference became large enough in the terminal stages to account for the depletion in volatile substances (*16*).

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