FORMATION OF LARGE IMPACT BASINS ON THE MOON: NUMERICAL SIMULATIONS OF IMPACT CRATERING ON SPHERICAL TARGETS : Toshiko Takata, Geological Institute, University of Tokyo, Tokyo, 113 JAPAN

Numerical simulations of impact cratering on spherical bodies are presented in order to investigate the impact parameters for the formation of South Pole-Aitken (SP-Aitken) basins, whose diameter is larger than the radius of the moon. Results show that some 50 % of the impact energy to form the same size of SP-Aitken basin on the plane target is required to form it on the moon. The excavated depth is estimated as $\sim$ 100 km. The result indicates that possible basin materials of SP-Aitken are (1) the mixture of the upper mantle, lower crust, and the exotic ejecta, or (2) undifferenciated primitive mantle materials. Moreover, the impact of a body of $\sim$ 300km-radius with the velocity of ≤ 2 km/s can not only form SP-Aitken basin, but supply the excess mass of the crust on the far-side as ejecta.

Clementine revealed the entire structure of South Pole-Aitken (SP-Aitken) basin on the lunar far-side. The diameter is 2500 km [1], which is larger than the radius of the moon (1730 km). In the formation-stage of large impact craters, such as SP-Aitken, lunar sub-surface materials are excavated and exposed on inside craters. In order to estimate the depth from which sub-surface materials are originated, scaling of crater dimensions [2,3] is an effective tool. However the present crater-scaling is generally applicable to impact on infinite plane targets. In the case that the size of impact craters is equivalent to the size of target bodies, such as SP-Aitken, the spherical shape of targets is required to be taken into account.

In order to investigate effects of the spherical shape of targets on cratering parameters, such as crater sizes and excavation depths, numerical simulations of impact cratering on spherical targets are conducted using SPH (Smoothed Particle Hydrodynamics) code [4]. SPH method is suitable for the complex motion of materials. Our SPH code has been tested in various impact problems [e.g.,5]. To impactors and targets, Tillotson Equation of State for Anorthosite is applied. The radius of the spherical target is assumed 1730 km. Impact velocities (V) and radii (r) of the impacting bodies to form craters with the same size of SP-Aitken basin on infinite plane surfaces, such as, V = 5 km/s and r = 250 km [fig.1], or V = 20 km/s and r = 100 km, are applied [3].

In the case of the impact on the spherical surface, resulting flow fields of target materials show that the ejection-angle from the surface is larger than the case on the plane surface, as the distance from the impact site becomes larger. This observed flow fields can be explained by Z-model [6]. As a result, the ratio of the area covered by the ejecta relative to the crater area becomes smaller than that of the plane target.

The maximum penetration depth at the impact site on the spherical target is the same as the one on the plane target ($\sim$ 700 km). The result indicates that the same excavation depth of $\sim$ 125 km can be achieved in both impacts on the spherical body and on the plane target [3].

However, due to the curvature of the free-surface of a spherical body, the shock pressure on the free surface at some arc-distance on the spherical target becomes larger than that at the same distance on the plane target. As a result, the crater diameter measured

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along the arc of the spherical body is enlarged compared with the diameter of the impact crater on the plane target.

Assuming that shock waves propagate radially from the impact point, the diameter of a crater calculated from the scaling of crater dimensions for the plane target, D', [2,3] can be replaced by; $D' = 2R\sin(D/2R)\cos(D/4R)$, where R and D are the radius of the spherical target and the arc-diameter of the crater on the spherical target, respectively. Applying this relation to the formation of SP-Aitken crater, D' is 2100 km, or $\sim 0.8D$. This indicates that impact parameters to form craters of $\sim 0.8D$ on the plane target can form SP-Aitken basin on the moon. That is, the impact energy to form SP-Aitken on the moon is some 50 % of the impact energy to form the same size of the crater on the plane target. Then the maximum penetration depth and the corresponding excavation depth of SP-Aitken basin on the moon are, 600 km and 100 km, respectively.

Multi-spectra data obtained by Clementine indicates that the rock materials in SP-Aitken basin could be originated from the lower crust, since the medium content of iron in materials on the basin [7]. However our numerical results indicate that materials at the depth of 100 km, e.g., of the upper mantle can be directly excavated and deposited on the basin of SP-Aitken. Therefore possible alternative interpretation of the basin materials of SP-Aitken is (1) the mixture of the materials from the upper mantle, the lower crust, and exotic ejecta, or (2) undifferentiated primitive mantle materials.

The volume of the interior of SP-Aitken basin is approximately equivalent to the excess volume of the highland on the lunar far-side [1]. Moreover the average thickness of the crust of the far-side is 8 km thicker than the one of the near-side [1]. This excess mass of the far-side is equal to the mass of the projectile of $\sim$ 300 km-radius. The projectile of this size can form SP-Aitken basin with the impact velocity of $\leq$ 2 km/s. With this low velocity, it is plausible that most of the ejecta could deposit on the highland area on the far-side. Thus, the projectile may have played a principle role in supplying the excess mass of the crust of the far-side.

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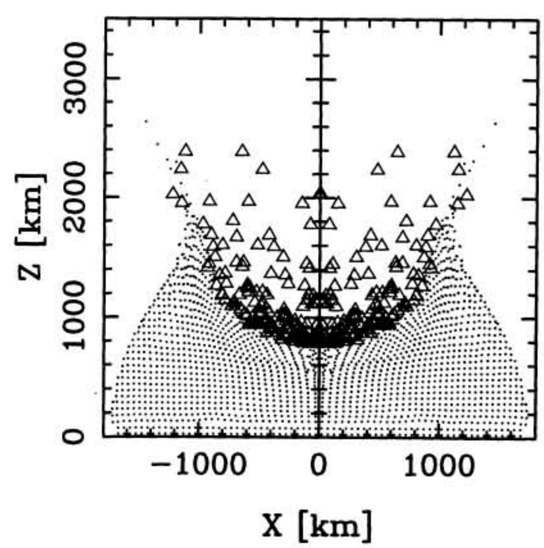

Figure 1. SPH simulation of impact of 500 km-size projectile on the moon with the velocity of 5 km/s at 13 minutes after the impact.