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Multiringed basins and ejecta from them have had a profound effect on large areas of the Moon. Volumes excavated during their formation and distribution of the ejected volumes are, thus, critical to understanding the geology at most Apollo landing sites, orbital remote sensing data, and lunar topography. Geologic mapping of the Orientale basin, theoretical considerations, and terrestrial analog studies reveal several complicating factors affecting simplistic approaches to these problems: (1) lobes and ray-like deposits of ejecta are concentrated along certain azimuths, (2) the general distribution of ejecta may be asymmetric, (3) ejecta from craters in horizontally layered targets are zoned and compositions of the ejecta vary in a regular manner from the crater rim crest, and (4) the interaction of ejecta traveling at high velocities along various trajectories with the lunar surface is complex.

Preliminary analyses of lunar orbital gravity data (Sjogren et al., 1972, and unpublished data) indicate the mass deficiency of Orientale is equivalent to a volume between 1 and 3 million cubic kilometers for the present basin within the Cordillera ring. The analyses involve an estimate of the gravity anomaly prior to the introduction of a plug of volcanic material in the center of Orientale. One analysis using the thin disk formula yields volumes near 2 to 3 million cubic kilometers. The second analysis uses mass points furnished by W.L. Sjogren for the northern part of Orientale and yields volumes of 1.3 to 1.4 million cubic kilometers. Here, the effect of dense volcanic material in the basin center was accounted for by reversing the sign of mass points over the central mare material. A second estimate of the volume of Orientale assumes the equations for the relationships between crater depth-diameter and rim height-diameter for craters larger than about 17 km across (Pike, 1972) are applicable to large basins which are curved disks. For a basin radius of 450 km, crater depth measured from the rim is 7.35 km and rim height above the local surroundings is 2.71 km. The volume of the curved disk 4.64 km deep is about 3.0 million cubic kilometers. Another estimate for a parabolic-shaped basin, ignoring curvature of the Moon, yields a crater volume of about 0.9 million cubic kilometers. A third estimate of volume, employs a model for ejecta thickness at the rim and an inverse cube function for variation of ejecta thickness with distance from the crater (McGetchin et al., 1973) For a basin with a radius of 450 km, the ejecta thickness at the rim is 2.0 km and the volume of the ejecta is about 2.6 million cubic kilometers. Thus, it appears to us that the volume ejected from Orientale was greater than 1 to 3 million cubic kilometers and, if post-basin formation adjustment occurred, the volumes estimated using gravity and crater size could be low.

Near the Cordillera Mountains, 500 to 600 km from the basin center, ejecta thicknesses estimated from buried craters range from 3 to 4km. (Table 1). Ejecta on the north and south Cordillera rim may be very thick. Here the buried craters are not seen and may be so completely inundated that they cannot be recognized. Ejecta thin outward. Local lobes of ejecta thicker than $\frac{1}{2}$ km are present 1175 km from the basin center. The farthest measurable thickness was a lobe 0.1 km thick 1420km from the basin center.

The great thicknesses of ejecta at various distances are incompatible with the volume estimates above. Indeed, equations used for the estimate of

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volume using the ejecta model above yields an ejecta thickness of only 0.8 to 1.5 km at 600 to 500 km from the basin center and a thickness at the rim that is smaller than those estimated from buried craters outward of the rim. If the ejecta average thickness at 600 km is 3.0 km, as implied by buried craters, and ejecta thickness varies as the inverse of the cube of the distance from the basin center, the ejecta thickness at the Cordillera would be 7.0 km and the ejecta volume would be 9 million cubic kilometers. Thus, it is entirely possible that the ejecta from Orientale is much larger than a few million cubic kilometers.

Considerable amounts of ejecta, partly ballistic, may have traveled farther than 1420 km. An equivalent thickness of more than 8m may have impacted the lunar surface 3,000 km from the center of Orientale. Concentration of ejecta on selected azimuths as lobes and rays imply such ejecta need only occur locally. This ejecta would impact the lunar surface at velocities of about 1.6 km/sec to 2.3 km/sec depending on the trajectory. Interaction of ejected debris with the lunar surface is complex and depends on velocity at impact, trajectory, grain and fragment size-frequency distributions, sequence of impacting grains, local concentrations of ejected debris, and other factors.

Simple extrapolation of ejecta thickness results from Orientale to the Imbrium basin indicates substantial thickness of ejecta ($\approx$0.3-0.5 km) could be deposited up to 1700 km from the center of Imbrium. This, when combined with photogeologic evidence, shows that large amounts of material from Imbrium reached the Apollo 16 landing site. Such a conclusion suggests a potential conflict when considering the difference in samples returned by Apollo 14 and 16. A conflict does not necessarily exist if the lunar crust is layered or inhomogeneous. Ejecta from radially symmetrical terrestrial impact and explosive craters in layered materials are zoned with materials from the deepest horizons near the rim and those from more shallow horizons farther out. Oblique impacts could alter this general zonation of ejecta and deposit materials from deeper horizons chiefly on the "down-range" side of the crater. Thus, samples from Apollo 14 and 16 may represent materials from different layers on the Moon.

Smooth plains are part of the ejecta from large impact basins (Eggleton and Schaber, 1972) as well as smaller craters (Head, 1972). This is clearly illustrated at Orientale where plains units occur: (1) as isolated patches in the braided and lineated ejecta, (2) as surfaces of flow lobes clearly related to Orientale, and (3) possibly, as crater filling materials beyond the lobes and braided-lineated ejecta. Thus, smooth plains are part of the ejecta from multi-ringed basins and no additional mechanisms are required to produce them. However, other mechanisms, such as secondary impacts, downslope mass movements volcanic flows, and ejecta from countless lunar impact craters may affect pre-existing plains, and form some plains.

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I. Table of thicknesses of Orientale ejecta estimated from buried craters and flow lobes using depth-diameter model of Pike (1972).

	Latitude	Longitude	Range	Thickness	Diameter
Orientale	19°S	94°W	0	0	900 km
Lamarck D	25°S	73.6°W	600 km	4.0 km	115 km
Lagrange K	30.6°S	70.2°W	742	1.6	25
Rocca	13°S	72.5°W	652	3.6	82
Unnamed crater	16.5°S	72.2°W	634	2.6	25
Darwin B	20.0°S	72°W	658	2.4.3.2	53
Near Rocca J	15.0°S	74.5°W	578	3.3	60
Rocca Z	16.0°S	75.5°W	528	3.1	46
Unnamed crater	1.5°N	88°W	646	3.2	54
Unnamed crater	4.5°N	87.5°W	738	1.6	75
Sundman	11.0°N	91.5°W	913	1.0	39
Unnamed crater	13.5°N	91.2°W	989	2.4	18
Unnamed crater	14.6°N	91.5°W	1022	1.5	30
Hartwig	6.0°S	80.5°W	561	3.7	84
E. of Bouvard	40.5°S	77.5°W	780	3.2	51
Inghirami Q	48.5°S	73.0°W	1032	3.1	47.5
Ejecta Lobe	51.0°S	69.0°W	1140	0.3	na
Unnamed crater	51.6°S	79.0°W	1051	1.8.2.2	15
Unnamed crater	38.5°S	85.5°W	632	3.3	60
Thin flow	54°S	50°W	1420	0.1	na
Lagrange L	32°S	65°W	883	0.7	18
Unnamed crater	18.0°N	95.5°W	1153	3.1	45
in Hertzsprung	4.5°S	125°W	1017	0.6	5
in Hertzsprung	1.0°S	129°W	1175	0.6	16