pIcr., rim material, hummocky. Forms narrow poorly mappable, low rampart around

pIcw1, wall material. Forms moderate to gentle slopes in Longomontanus; interrupted

pIcf₁, floor material. Exposed only in Longomontanus and crater west of Weigel B;

pIcp₁, peak material. Mapped only in Longomontanus; smoother than unit pIcp₃

by broad hummocks and irregular terrace remnants; fairly heavily cratered. Mapped

crater Schiller S; rim crest discontinuous and wholly subdued

as buried in other craters

Material of impact craters

*Albedo described qualitatively because mapped area

is in limb region of Moon where existing measure-

ments do not permit better definition. Nearer center

of disk units like map units Cs and Cd have typical

approximate maximum range of albedo values in

normal albedos of 0.16 and 0.08, respectively; this i

Schiller quadrangle.

ally expressed wall and rim of craters buried by

regional units

GEOLOGIC MAP OF THE SCHILLER QUADRANGLE OF THE MOON

GEOLOGIC ATLAS OF THE MOON SCHILLER QUADRANGLE I-691 (LAC 125)

GEOLOGIC SETTING The Schiller quadrangle is in the southwest quadrant of the earthside hemisphere of the Moon, about 600 km south of the Humorum basin. Cratered terra occupies most of the quadrangle; the most prominent feature is the footprintshaped crater Schiller. A large area of plains, here called the Schiller plains, occurs in the western part of the quadrangle, partly filling the Schiller basin, an old structure defined by two rings of mountainous terra (Hartmann and Kuiper, 1962). Geologic units of regional extent unrelated to basins cover most of the region, but some units and structures are related to the Orientale basin, more than 1,000 km to the west-northwest.

STRATIGRAPHY Because the quadrangle is far from the Mare Imbrium area where the lunar time-stratigraphic sequence was defined (Shoemaker and Hackman, 1962) it is

difficult to assign ages to the stratigraphic units. The problem is dealt with by use of a sequence of inferred relative ages for craters established by Pohn and Offield (1970) on the basis of morphologic freshness. The sequence is divided into morphologic stages assigned arbitrary numbers in a scale from 7.0 (youngest) to 0.0 (oldest). These stages (not given numerically on the present map) are here tentatively correlated with the established lunar time-stratigraphic sublivisions (Shoemaker and Hackman, 1962 as revised by McCauley, 1967a, and Wilhelms, 1970). For this correlation, a crater-age number of 4.2 has been assigned to the beginning of the Imbrian Period, the time of formation of the Imbrium basin, on the basis of the oldest craters superposed on the basin ejecta blanket. The Imbrian-Eratosthenian and Eratosthenian-Copernican boundaries are given crater-age numbers 5.5 and 6.0 respectively (slightly older than the type craters), because changes in state of preservation of ejecta at those ages are conspicuous. Informal subdivisions here defined, and used on the map, are early and late Copernican and early and late Imbrian epochs (late Imbrian time beginning with formation of the Orientale basin), and three intervals of pre-Imbrian time, with boundaries arbitrarily set at 2.0 and 3.0 on the crater-age scale. The complete correlation (numbers inclusive) is: Copernican Period, 7.0-6.5 (late), 6.4 6.0 (early); Eratosthenian Period, 5.9-5.5; Imbrian Period, 5.4-4.8 (late), 4.7-4.2 (early); pre-Imbrian time, 4.1-3.0 (late), 2.9-2.0 (middle), 1.9-0.0 (early). The geologic units of the quadrangle are assigned limiting ages on the basis of their uperposition relations with craters of known positions in the above numerical scale and thereby are correlated with the standard lunar time-stratigraphic se-Pre-Imbrian materials.-Blocks of mountainous terra (unit pIu) occur in two iscontinuous rings which outline the Schiller basin. The extreme degradation of the basin rings and of the craters superposed on them indicates that the basin is the oldest structure in the quadrangle. Much of the south-central part of the quadrangle is occupied by similar degraded mountainous terrain which may con-

sist partly of ejecta from the Schiller basin and partly of the ancient terra surface on which the basin formed, presumably by impact. Terra-mantling material.—Most of the terra in the quadrangle is moderately cratered, with a gently rolling to finely and irregularly hummocky surface in the intercrater areas. Material with this hummocky surface texture (unit It) partly fills valleys along the bases of mountainous terra blocks. It also appears to partly or completely cover rims of large degraded pre-Imbrian craters so that much of their topographic expression is so muted that a rim unit cannot be mapped. That this is an effect of mantling by a local superposed unit is indicated by the fact that craters of apparently similar ages elsewhere on the Moon commonly have distinct raised rims where such a hummocky surrounding unit is not present In the Schiller quadrangle, the older the crater, the lower its rim and the greater the opportunity for more complete apparent mantling by materials deposited later; few middle or lower pre-Imbrian craters have evident rims, and their walls also appear to be mantled, whereas only the low parts of upper Imbrian crater rims appear to be covered. The mantling material is inferred to have covered the floors of many old craters and is mapped as patches, surrounded by younger plains material, in some craters. The mantling material is believed to be mostly volcanic in origin, possibly ash flows of variable thickness. Source vents have not been recognized but must be numerous to account for the great lateral extent of the unit in this area and elsewhere to the east in the southern highlands. Part of the unit may be colluvium of local derivation or a regolith developed essentially in place, but the general lack of topographically high source areas for a unit of such extent, and its apparent early (and possibly early late) Imbrian age everywhere, based on crater superposition relations, reinforce the interpretation of general volcanic origin. In the northwest corner of the map, around the crater Nöggerath and west of

the crater Schiller, part of the coarsely lineated material mapped as unit It resembles material of the Orientale basin ejecta blanket (McCauley, 1968; Hartmann and Yale, 1968) elsewhere named and mapped as the Hevelius Formation (McCauley, 1967b). The lineations mostly appear to be structural in nature and part of a system of Orientale-basin radial "sculpture," but some, particularly where they have a slightly braided pattern, may be related to ejecta-blanket deposition. Part of this terrain may be ejecta blanket deposits, as may some of the surface mantle on the finely lineated and hummocky area east of Schiller; the distinction of possible eject blanket materials and unit It cannot be made with certainty from

Other probable volcanic mantling material occurs as small patches on the wall of the crater Longomontanus and the rims of Zuchius and Bettinus; thus, the material appears to be younger than Copernican craters and rays and is, therefore, the youngest material in the quadrangle. Plains-forming material.—Materials with smooth, nearly flat surfaces (unit Ip) partly fill most pre-Eratosthenian craters and occupy many topographic lows at various levels in the intercrater areas. On these plains surfaces, small craters (<1 km) are approximately twice as numerous as on mare surfaces of similar material also has higher albedo than the mare materials. These differences may indicate that plains have abundant small volcanic craters on them and are of di erent composition than mare materials. The plains embay materials identified as ejecta from the Orientale basin and form floors without visible structure in craters whose walls are broken by structure related to the formation of the Orientale basin. By tentative correlation of crater sequence and time-stratigraphic units, this indicates a lower limit of late Imbrian time for the formation f the plains. An upper limit of earliest Eratosthenian time is suggested by the act that no crater mapped as Eratosthenian is filled by plains material. Elsewhere, similar plains materials have been considered (Howard and Masursky 1968; Wilhelms, 1968) as ponded volcanic terra mantling materials (similar to the unit here called terra mantling material), thick enough to cover underlying topography and form smooth surfaces. In the Schiller quadrangle and elsewhere in the southern highlands, however, a small difference seems indicated between ages of the plains material and terra-mantling material (or its equivalent in other areas). Some craters apparently are superposed on terra-mantling material, yet are filled by plains material; moreover, terra-mantling material is structured and the plains are not (although terra mantling material may be thin enough to show underlying structure). Also, contact relations suggest sharp truncation and embayment of terra-mantling material by the plains material. Therefore, the plains material does not seem to be a ponded facies of terra-mantling material. On the other hand, if plains material is a separate localized volcanic deposit, the occurrence of so many individual source vents for it, only in topographic lows, seems implausible. The problem remains unsolved.

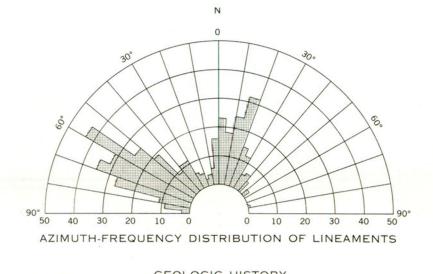
A younger, darker plains unit (diagonal line pattern on map) covers most of the Schiller plains. It is similar to mare units of the western part of the Moon in its low albedo and low density of small craters. The low albedo of the plains appears to extend across areas of gentle topography of Orientale satellitic materials and unit It in the Schiller plains, suggesting that dark material forms a thin cover in those areas. Because of this the dark material is interpreted everywhere as a thin blanket of relatively young ash-flow and ash-fall material, covering older smooth plains material which fills most of the Schiller basin and adjacent units of low topographic expression. Ridges and one possible dark-halo crater within the dark-plains area may mark source vents for the dark material; this association of features is similar to that in many mare areas (for example, Crater materials. - Materials of craters of all ages occur in the Schiller quadrangle, and nearly all the craters are circular to somewhat polygonal. As discussed above, the relative ages of these craters have been tentatively correlated by

means of morphology with the standard Moon-wide time-stratigraphic systems of the U.S. Geological Survey (pre-Imbrian to Copernican). Of particular interest are large clusters of craters and associated ejecta, espec ally those at the west edge of the quadrangle (units Iso, Ifo). These clustered craters are identified as secondary craters formed by ejecta from the Orientale basin because they are part of a radial array which extends hundreds of kilometers outward from the basin ejecta blanket. Also, crater-age criteria indicate that they are the same age as the basin and the blanket. Craters 5 to 15 km in diameter, of Orientale age but not necessarily in linear radial groups, are unusually abundant in the quadrangle and probably are satellitic to Orientale. The Orientale basin is inferred to have formed approximately in the middle of the Imbrian Period. Schiller may not be an impact crater. Its elongate shape could be due to coales cence of two or three round impact craters, but this seems unlikely because doublet craters of probable impact origin generally have some vestige of a wall between them (Milton, 1968) and Schiller apparently lacks such a wall. The crater Schiller is on a ring structure of the Schiller basin, and the axis of the crater is alined with a poorly developed tectonic-grid direction, which is marked by the linear ranges on its floor and the conspicuous trough extending to a smaller crater from the southeast end of the crater. As Schiller appears to extend along a fault, it may have formed as a single elongate volcano-tectonic feature or by the coalescence of two slightly elongate smaller calderas. If Schiller is a volcanic crater, determination of its age by the age criteria used for impact craters may not be valid. It is, however, older than unit It and still only moderately subdued in appearance; this and superposition relations with craters of probable impact origin indicate a late pre-Imbrian age. Crater Rost B and the craters on the eastern rim of Schiller also may be of volcanic origin because of their association with Schiller. The crater Scheiner B has unusual rim and central peak morphol-

STRUCTURE

(unit Ich), occur east and west of the crater Scheiner.

Linear west-northwest-trending valleys are prominent in the west half of the quadrangle. They are radial to the Orientale basin and are considered to have been produced by vertical fault movements resulting from the basin-forming event. Long narrow ridges on the Schiller plains alined with these structures probably are volcanic vents localized by faults. A system of ridge and valley ineaments of north-northeast trend is also best developed in the west half of the quadrangle. The orientation of these lineaments suggests that they are lines of radial structure associated with the Humorum basin. Others are concentric to Orientale and may be related to that basin. The older, possible Humorum lineaments may have been reactivated by the Orientale event. Lineaments are much less abundant and smaller in the east half of the quadrangle. The accompanying figure shows the azimuth frequency distribution of lineaments. The two major systems are apparent. Low hummocky ridges and intervening valleys in the large clusters of Orientale satellitic materials which occur in the Schiller plains area are also mapped as neaments. These may be structural in origin but are more likely depositional. They probably formed by outward spray of ejecta in a herringbone pattern from a linear focus of impacting material. Similar patterns are very clear in satellitic materials around large fresh impact craters.



GEOLOGIC HISTORY The earliest decipherable event in the area was the formation of the Schiller basin. Aside from formation of major craters such as Longomontanus, Clavius, and Schiller, and possible faulting associated with the Humorum basin-forming event, no major geologic event is recorded until Imbrian time, when widespread mantling of the terra took place (unit It). In late Imbrian time much faulting cratering, and deposition of ejecta occurred as a result of the event which formed the Orientale basin. This event was followed by the emplacement of smooth plains materials which fill most older craters, the Schiller basin, and many low areas in the terra. The last major event was the emplacement of dark material as a surficial covering in the Schiller plains area. Formation of the crater Zuchius in late Copernican time resulted in widespread distribution of fresh ejecta across the southwest corner of the quadrangle. Still more recently, dark material was emplaced in three small areas (unit Cd). Impact cratering and mass wasting have occurred throughout the history of the quadrangle, covering many surfaces with debris and exposing others. Bright surfaces are probably areas where materials have been recently exposed; they are mapped as unit Cs.

REFERENCES

Carr, M. H., 1966, The geology of the Mare Serenitatis region of the Moon, in Astrogeologic Studies Ann. Prog. Rep., July 1, 1965-July 1, 1966, pt. A:U.S. Geol. Survey open-file report, p. 11-16. Hartmann, W. K., and Kuiper, G. P., 1962, Concentric structures surrounding lunar basins: Arizona Univ. Lunar and Planetary Lab. Commun., v. 1, no. 12, p. 51-66. Hartmann, W. K., and Yale, F. G., 1968, Lunar crater counts, IV-Mare Orientale and its basin system: Arizona Univ. Lunar and Planetary Lab. Commun., v. 7, Howard, K. A., and Masursky, Harold, 1968, Geologic map of the Ptolemaeus quadrangle of the Moon: U.S. Geol. Survey Map I-566. McCauley, J. F., 1967a, The nature of the lunar surface as determined by systematic geologic mapping, in Runcorn, S. K., ed., Mantles of the earth and terrestrial planets: London, John Wiley & Sons, p. 431-460. McCauley, J. F., 1967b, Geologic map of the Hevelius region of the Moon: U.S. Geol. Survey Map I-491. _____1968, Geologic results from the lunar precursor probes: Am. Inst. Astronautics and Aeronautics Jour., v. 6, no. 10, p. 1991-1996. Milton, D. J., 1968, Structural geology of the Henbury meteorite craters, Northern Territory, Australia: U.S. Geol. Survey Prof. Paper 599-C, p. C1-C17. Pohn, H. A., and Offield, T. W., 1970, Lunar crater morphology and relative age determination of lunar geologic units, in Geological Survey research 1970: U.S. Geol. Survey Prof. Paper 700-C, p. C153-C169; also 1969, U.S. Geol. Survey open Shoemaker, E. M., and Hackman, R. J., 1962, Stratigraphic basis for a lunar time scale, in Kopal, Zdeněk, and Mikhailov, Z. K., eds., The Moon—Internat. Astron. Union Symposium 14, Leningrad, 1960, Proc.: London, Academic Press, p. 289-300. Wilhelms, D. E., 1968, Geologic map of the Mare Vaporum quadrangle of the Moon: U.S. Geol. Survey Map I-548. Wilhelms, D. E., 1970, Summary of lunar stratigraphy—telescopic observations:

U.S. Geol. Survey Prof. Paper 599-F, p. F1-F47.