The moon, 8½ days old, as seen through the telescope.

First quarter, as seen on the sculptured moon.

Last quarter, as seen on the sculptured moon.

The moon, 20½ days old, as seen through the telescope.

How a Plastic Model of the Moon Was Made

The Hemisphere of the Moon Constructed After Telescopic Photographs

By Herbert Collier

AFTER some years of telescopic observation with a Brashear telescope I determined to undertake the task of sculpturing the moon, mainly for the purpose of attaining greater familiarity personally with every detail of the surface.

When you consider that the artist's model was some 240,000 miles away and had gained a reputation through the ages of being "fickle," some of the difficulties become apparent. Every day the moon has a different appearance—a new dress every sitting. As the sunlight creeps over the hills and lights up the mountain peaks, the view of yesterday changes, and quite a new aspect results. New valleys, great yawning craters jump into view with their dark depths untouched by even a glimmer of twilight, forming a background of Rembrandt's choosing. Continually the terminator, the irregular dawn line dividing light and darkness, is moving forward. On the earth this travels at the rate of about 1,000 miles an hour, completing the circuit of the globe in one day. On the moon this movement is about 225 miles per day, or nearly 10 miles an hour, for the earth turns round 29½ times to one revolution of the moon.

The details of craters—breadth and depth, a crag here, a precipice there—show clearly, contrasted by the shadows. But as the sun rises all this passes into

blurry confusion in the fierce light of overhead rays. In such a moving picture there is a peculiar fascination. A new panorama presents itself each night to the watchful eye. To see it all is impossible, as the moon is in the visible sky for but a few hours comparatively, and nightly vigils with the telescope are sure to be interrupted frequently by cloudy weather or bad atmospheric conditions. Thus a long course of looking is obligatory before the student by personal observation knows the surface of the moon thoroughly.

Though my eye had registered through the telescope thousands of impressions of the surface markings of the moon, I dared not trust that organ solely in transferring them to sculpture. Accuracy of result demanded exact measurements. Telescopic photographs present an unchanging record. They give an indelible impression of what is revealed, and such permanent record is ready for investigation at all times. Beyond question, photography pre-eminently has enabled astronomy to merit the title given it to-day "the most exact of sciences." Therefore I made, as the foundation of my work, the best series of photographs of the moon that the world has to-day, which is known as the Paris Atlas.

Twenty years ago M. Loewy, the gifted director of the Paris Observatory, with his colleague, M. Puiseux,

undertook the systematic photographing of the moon. A unique telescope was designed, and elaborate plans and specifications made for this remarkable undertaking. The instrument was an ingenious combination of a huge object-glass or light collector nearly two feet in diameter and mirrors. Equatorially mounted and driven by clockwork, the refracting lens faithfully followed the object across the sky, while the mirrors, two in number, were so arranged as to convey the image thus secured through a tube in the wall to the eye-piece situated within a comfortable room. Here the camera was attached, and the men worked free from the usual bodily discomforts associated with the ordinary telescope.

While some of the finest individual photographs of the moon have been taken by the great telescope at the Yerkes Observatory, which is the largest refracting telescope in the world, nothing can compare with the series secured by the Paris astronomers through years of devoted effort. Thousands of photographs were taken of the moon at all stages of its progress from new to full, and then on to new again. Possibly twenty would be secured one night and but one selected as good enough to enter the atlas. These pictures form a wonderful catalogue of the topography of the moon, presenting far more minute details of the surface of our own satellite

Full moon as seen in the telescopes.

Full moon as it appears on the model.

- 1 Kästner
- 2 Maclaurin
- 3 Lapeyrouse
- 4 Anser
- 5 Behaim
- 6 Hecatäus
- 7 Philips
- 8 Legendre
- 9 Haze
- 10 Furnerius
- 11 Marinus
- 12 Oken
- 13 Fraunhofer
- 14 Brisbane
- 15 Hannon
- 16 Pentecoulant
- 17 Biela
- 18 Hagecius
- 19 Helmholz
- 20 Boussingault
- 21 Boguslawsky
- 22 Manzinus
- 23 Mutus
- 24 Simpelius
- 25 Curtius
- 26 Pentland
- 27 Zach
- 28 Jacobi
- 29 Lilius
- 30 Cuvier
- 31 Bacon
- 32 Pitiscus
- 33 Rosenberger
- 34 Vlacq
- 35 Steinheil
- 36 Janssen (S)
- 37 Fabricus
- 38 Metius

- 78 Bianchini
- 79 Playfair
- 80 Fermat
- 81 Pons
- 82 Azophi
- 83 Abenezra
- 84 Donati
- 85 Faye
- 86 Almanon
- 87 Catharina
- 88 Cyrillus
- 89 Theophilus
- 90 Beaumont
- 91 Madler
- 92 Torricelli
- 93 Hypatia
- 94 Delambre
- 95 Taylor
- 96 Kant
- 97 Descartes
- 98 Abulfeda
- 99 Hipparchus
- 100 Albategnius

NAMES CORRESPONDING TO KEY-MAP, LOCATING ALL PROMINENT OBJECTS ON THE MOON.

- 220 Wargentini
- 221 Weigel
- 222 Röst
- 223 Schiller
- 224 Bayer
- 225 Schickard
- 226 Inghirami
- 227 Lehmann Bouvard
- 228 Drebbel
- 229
- 230 Clausius
- 231 Lacroix
- 232 Piazzzi
- 233 Lagrange

- 256 Pictet
- 257 Nasireddin
- 258 Miller
- 259 Sasserides
- 260 Wilhelm I.
- 261 Heinsius
- 262 Hainzel
- 263 Lexell
- 264 Hell
- 265 Gauricus
- 266 Wurzelbauer
- 267 Pitatus
- 268 Hesiodus
- 269 Cichus

- 292 Purbach
- 293 Lacaille
- 294 Delaunay
- 295 Thebit
- 296 Right Wall
- 297 Arzachel
- 298 Alphonsus
- 299 Ptolemäus
- 300 Wm. Herschel
- 301 Alpetragius
- 302 Lassell
- 303 Davy
- 304 Lalande
- 305 Flammarion

- 416 Hahn
- 417 Berossus
- 418 Burckhardt
- 419 Gauss
- 420 Geminus
- 421 Berzelius
- 422 Messala
- 423 Franklin
- 424 Cepheus
- 425 Oersted
- 426 Volta
- 427 Long
- 428 Mercurius
- 429 Endymion

- 452 Burg
- 453 Plana
- 454 Posidonius
- 455 Chacornac
- 456 Römer
- 457 Macroibus
- 458 Proclus
- 459 Taruntius
- 460 Maskelyne
- 461 Sabine
- 462 Ritter
- 463 Arago
- 464 Sosigenes
- 465 Godin
- 466 Rhaeticus
- 467 Tresnecker
- 468 Agrippa
- 469 Ukert
- 470 Hyginus
- 471 Boscovich
- 472 Manilius
- 473 Menelaus
- 474 Maclear

- 604 Epigenes
- 605 Fontenelli
- 606 Anaximenes
- 607 Carpenter
- 608 J. Herschel
- 609 Anaximander
- 610 Pythagoras
- 611 South
- 612 Harpalus
- 613 Xenophenes
- 614 Plato
- 615 Plato A.
- 616 Condamine
- 617 Bouguer
- 618 Straight Range
- 619 Cape Laplace
- 620 Cape Heraclides
- 621 Bianchini
- 622 Sharp
- 623 Mairan
- 624 Repsold
- 625 Harding
- 626 Gerard
- 627 Lavoisier
- 628 Ulugh Beigh
- 629 Lichtenberg
- 630 Otto Struve
- 631 Aristarchus
- 632 Herodotus
- 633 Schiaparelli
- 634 Seleucus
- 635 Kraft

- 39 Rheita
- 40 Stevinus
- 41 Snellius
- 42 Reichenbach
- 43 Petavius
- 44 Vendelinus
- 45 Langrenus
- 46 Webb
- 47 Messier
- 48 Goclenius
- 49 Guttenger
- 50 Capella
- 51 Isidorus
- 52 Colombo
- 53 Cook
- 54 Santbech
- 55 Bohnenberger
- 56 Fracastorius
- 57 Borda
- 58 Neander
- 59 Piccolomini
- 60 Stiborius
- 61 Riccius
- 62 Rabbi Levi
- 63 Zagut
- 64 Nicolai
- 65 Büshing
- 66 Buch
- 67 Maurolycus
- 68 Barocius
- 69 Licetus
- 70 Stöfler
- 71 Fernelius
- 72 Frisius
- 73 Pontanus
- 74 Aliacensis
- 75 Walter
- 76 Werner
- 77 Apian

- 101 Hind
- 102 Halley
- 103 Argelander
- 104 Airy
- 105 Réaumur
- 106 Sacrobosco
- 107 Schömbberger
- 108 Janssen
- 109 Horrocks
- 110 Rothmann
- 111 Lindenau
- 201 Newton
- 202 Moretus
- 203 Cysatus
- 204 Casalus
- 205 Klaproth
- 206 Wilson
- 207 Blancanus
- 208 Scheiner
- 209 Gruemberger
- 210 Clavius
- 211 Deluc
- 212 Kircher
- 213 Bettinus
- 214 Bailly
- 215 Zuchius
- 216 Segner
- 217 Mausen
- 218 Procyllides
- 219 Nasmyth

- 234 Fourier
- 235 Vieta
- 236 Palmieri
- 237 Cavendish
- 238 Henry
- 239 Byrgius
- 240 Darwin
- 241 Zupus
- 242 Fontana
- 243 Crüger
- 244 Billy
- 245 Trouvelot
- 246 Rocca
- 247 Grimaldi
- 248 Damoiseau
- 249 Riccioli
- 250 Lohrmann
- 251 Maginus
- 252 Longomontanus
- 253 Street
- 254 Saussure
- 255 Tycho

- 270 Capuanus
- 271 Ramsden
- 272 Vitello
- 273 Mercator
- 274 Campanus
- 275 Kies
- 276 Doppelmayer
- 277 Mersenius
- 278 Gassendi
- 279 Letronne
- 280 Billy
- 281 Hansteen
- 282 Flamsteed
- 283 Landsberg
- 284 Fra Mauro
- 285 Bonpland
- 286 Pamy
- 287 Guerike
- 288 Lubiniezky
- 289 Bullialdus
- 290 Agatharchides
- 291 Regiomontanus

- 306 Mösting
- 307 Birt
- 308 Prom. Aenarium
- 309 Huggins
- 310 Liebig
- 311 Lee
- 312 Hippalus
- 313 Schubert
- 402 Apollonius
- 403 Neper
- 404 Firmin
- 405 Condorcet
- 406 Auzout
- 407 Hansen
- 408 Picard
- 409 Cape Agarum
- 410 Albazen
- 411 Elismart
- 412 Orlani
- 413 Plutarch
- 414 Cleomedes
- 415 Tralles

- 430 Atlas
- 431 Hercules
- 432 De la Rue
- 433 Strabo
- 434 Thales
- 435 Democritus
- 436 Kant
- 437 Moigno
- 438 Euctemon
- 439 Challis
- 440 Gloja
- 441 Barrow
- 442 W. C. Bond
- 443 Ch. Mayer
- 444 Archytas
- 445 Alpine Valley
- 446 Aristoteles
- 447 Egede
- 448 Euclides
- 449 Alexander
- 450 Calippus
- 451 Bailly

- 475 Ross
- 476 Plinius
- 477 Jansen
- 478 Dawes
- 479 Vitruvius
- 480 Maraldi
- 481 Argaeus Mts.
- 482 Lemonnier
- 483 Bessel
- 484 Aratus
- 485 Linné
- 486 Conon
- 487 Autolycus
- 488 Aristillus
- 489 Theaetetus
- 490 Cassini
- 491 Protagoras
- 492 Peirce
- 493 Bernouilli
- 494 Timaeus
- 495 Scoresby
- 496 Goldschmidt
- 497 Meton
- 498 Kirchhoff
- 499 Schumacher
- 500 Hooke
- 501 Caesar
- 601 Anaxagoras
- 602 Philolaus
- 603 Birmingham

- 636 Cardanus
- 637 Galileo
- 638 Marinus
- 639 Reiner
- 640 Olbers
- 641 Hevel
- 642 East
- 643 Encke
- 644 Kepler
- 645 Kunowsky
- 646 Reinhold
- 647 Copernicus
- 648 Gay-Lussac
- 649 Tobias Mayer
- 650 Euler
- 651 Diophantus
- 652 Delisle
- 653 Gruithuisen
- 654 Helicon
- 655 Lavoisier
- 656 Mt. Pico
- 657 Mt. Piton
- 658 Kirch
- 659 Archimedes
- 660 Timocharis
- 661 Lambert
- 662 Pytheas
- 663 Eratosthenes
- 664 Stadium
- 665 Pallas
- 666 Schröter
- 667 Sömmering
- 668 Gambart
- 669 Briggs
- 670 Cavalierius
- 671 Rainbow Bay
- 672 Maupertius
- 673 Foucault

than we know of our earth in many regions. The atlas was to me a guide book superior to a personal visit.

Fearful lest through lack of knowledge of the technique of sculpture I should waste much valuable time, I devoted fully six months to the study of this special feature. Then after consultation with a number of skillful artists I commenced operations.

Plasticine appeared best suited to the conditions under which I was to labor. It is non-drying and responds quickly to manipulation with a tool. A sitting of three or four hours, then a day or two, and another sitting just as my spare time permitted, proved plasticine an excellent medium for the purpose.

"How big shall I make it?" was a troublesome question which received answer in the selection of a scale of 180 miles to the inch. The moon having a diameter of 2,160 miles, thus brought my work to a like measurement of 12 inches. This was a convenient workable basis and proved satisfactory in every respect.

Only half the moon is visible to us at any time, and, strange to say, it is always the same half. A presentation to "royalty" demands that madam turns not her back to the regal chair. The approach, the bow, and the retreat call for skillful manipulation of her troublesome train, but she must keep her face ever to the front. So the moon sedately circles about the earth, and in true subservience observes this custom with remarkable precision. Every 29½ days the moon makes the circuit of the earth. At the same time she turns completely round. Yet with provoking constancy does she keep that one side to us. A slight swaying of the ball called "libration" permits a peep at times of a little more of the "edges" than the exact half, which really makes a total of about 59 per cent of the whole surface presented at different times to the earth. Consequently, half a sphere is really all we need to represent the details of surface characteristics of the earth's satellite, which are known to mankind. Therefore, as a foundation for my model I constructed a hemisphere of selected well-dried wood, laminated to prevent warping. The entire surface was then liberally treated with shellac. With a diameter of 11 inches this wood core allowed a blanket covering of plasticine ½ inch in thickness, thus giving a total diameter of 12 inches. A board 16 by 24 inches served as the base, and to this was fastened the hemisphere of wood and plasticine. The preparations were complete. Noting the date, May 1st, 1913, actual operations commenced. It was eight months later when the finishing touches were applied.

The photograph of a ball such as the moon presents some peculiarities. Take a 12-inch photo of a 12-inch ball. Superimpose the apparent centers, at the same time wrapping the photo paper around the face of the hemisphere. It is immediately apparent that they do not correspond and will not fit. The photo paper lacks practically seven inches of covering its prototype. The reason for this is quite evident. If the photo is kept flat and vertical lines projected to the surface of the ball, they coincide perfectly. This tersely explains the method I adopted on account of its simplicity in transposing scale calculations.

A photo of the full moon is very much like the preliminary sketch of the landscape painter. The seas, those great dark regions which even the naked eye discerns plainly, are nicely outlined. Some of the more prominent craters are noted. The more important mountain ranges are roughly indicated. But the details of all these are to be shown later. I first selected such a picture, an excellent one from the 5-inch Brashear telescope of D. B. Marsh, Sc.D., F.R.A.S. Being just 12 inches in diameter, it served the purpose admirably of an outline sketch or key. Various points on this were chosen and soon projected onto the model. As the work progressed craters and prominent physical features, visible only in other photos, were first given their proper locations on this key, that they might thereby be accurately placed on the model.

Each Paris photo gave in great detail one small region. Possibly but one or two craters of importance would be shown. Another picture of the same region, but under different lighting conditions, would change the apparent physical features to a remarkable degree. Thus a number of pictures of every district, showing the changes produced by sunlight coming from the east or from the west, must be carefully compared in order to arrive at a full understanding of the real topography. With a hundred such photos before me constantly, this task was by far the greatest and of prime importance. There are no twilight shadows on the moon. A glance at a dark spot may lead to the conclusion that a great hole is there, to which the sunlight has not as yet been admitted. Further investigation of it in other pictures reveals the fact that there is no such cavity, and that the shadow is due to the peculiar conformation of an intervening hill. Though the shadows thus appear puzzling and are sometimes very misleading, they are quite necessary for an understanding of the height of a crater wall, and a hundred other measurements of the

various conformations of the surface. They simply require due consideration.

The moon is a dead world. The most minute investigation indicates that nothing could be more so. A dried up, wrinkled, wizened, scarred veteran, it bears the marks of terrible conflicts, of gigantic struggles. We know not its age. Did water once rush down those wondrous mountain gorges? Did the sea ripple and play about those towering capes Laplace and Heraclides and at times dash madly against those great precipices? We can only guess. Our fancy pictures, in the distant past, smiling vegetation, life, joy, and happiness in a world of glory. It is true there are some indications of this. But death came. Like a mummy it is to-day. Life departed, embalmed, naught remains but the shrunken, desiccated, cracked carcass. The beauty of life is gone. Its history, its experiences written in the shroud, are in mysterious hieroglyphics, of which man has been able to decipher but little. To-day no grass waves on the hillside. Not a single blade would give the weary traveler a welcome. No bird warbles his cheery song there. Not even the hated snake suns himself upon the many rocks. Not an insect flits about in quest of prey. Not a breath of air stirs. Not a sign of life appears anywhere. Inconceivable desolation!

Night comes. The sun sinks behind the lofty hills, and suddenly all is dark. No twilight softly intervenes. Cloudless the sky, devoid of air and moisture, no light is reflected or refracted. There can be no diffusion of sunlight under such conditions. Black night sits side by side with brilliant day wherever the rays of the sun are intercepted. Behind the jutting rock, beneath the ledge, within the cavern of broad entrance, it is night, though day reigns supreme with intense brightness all about.

It is quite a surprise to many to learn that the earth presents more light to the moon than it receives in return. Assuming that they possess the same reflective power, the surfaces compare as 27 to 2. Thus the earth should be credited with reflecting more than thirteen times as much light as its satellite. This light thrown upon the moon is known as "earthlight," and is in all respects similar to our moonlight. When the moon begins its monthly journey around the earth by passing between the sun and us, the earth is "full moon" to it, while that body presents the phase of "new moon" to us. Thus the greatest amount of "earthlight" reaches the dark portions of the moon at this time. It is this phenomenon which gives rise to that beautiful sight, "the old moon in the young moon's arms." As the age of the moon increases, this reflected light from the earth gradually lessens until there is none at full moon. Then as the moon nears the completion of its circuit the "earthlight" continues to increase in proportion.

While the moon is making this circuit of the earth 29½ of our days pass by. Yet she takes all this time to have but one day and one night. Day brings heat unbearable in its intensity. Scorching as the flames from the inferno, the sun pours his streams of fire hour after hour until the rocks fairly dance with molecular agitation. For fourteen days without a moment's relief this continues. Then with startling suddenness night appears. A temperature more than 200 degrees below zero assails all. Without the kindly protection of a cloud, stark naxed as it were, and thrust into a temperature of glacial cold from such a bed of warmth, the results must be disastrous. Such extremes of heat and cold as these cannot but result in anything less than gigantic destruction. Great yawning chasms appear everywhere on the moon, some of which extend for hundreds of miles. Close scrutiny of these numerous cracks, a thousand of which have been charted, suggests to the observer the possibility of some slight extra disturbance resulting in a general disintegration of the whole satellite.

Seismic convulsions appear to have taken place at certain centers in the early history of the moon, producing remarkable results. The exterior of the molten mass had cooled sufficiently to form a crust, a brittle glass-like covering. A large number of the so-called craters had formed. Then with further cooling of the molten interior tremendous expulsive force was exerted, bursting the outer shell and throwing out great radiating cracks in all directions, like spokes in a wheel. Lava then oozed up through these openings, in some cases but partly filling them, in others overflowing. Congealing and solidifying under different conditions from the remaining crust, this formation is quite distinctive in appearance, showing as bright streaks. The crater Tycho at the south pole is the center of the greatest system of these light streaks, and thus was at one time in the throes of a seismic disturbance of unparalleled magnitude. Some of the streaks from this center appear to encircle almost half the moon, thereby indicating the violence attendant upon this great shock.

In order to give to the eye the effect attained by telescopic observation, I took the liberties of the artist and departed from scale measurements in one respect. With

180 miles to the inch, a distance of 2 miles on the moon would be 1/90th of an inch on the model. This is less than the thickness of your business card. A lunar precipice of two miles height would be a very prominent object under proper lighting conditions, and be worthy of special attention. Yet an elevation of but 1/90th of an inch on the model would be merely the thickness of a coat of paint! Therefore the elevations were accentuated in order to produce to the eye a natural appearance, for the strict adherence to scale in this respect would create misconceptions. Careful comparison of photos of the real moon and the sculptured one, under approximately similar lighting, shows marked contrast. But this was a feature that was not in the least considered important. My aim was not to attain photographic similarity, but to convey to the eye under daylight conditions details apparent only on rare occasions with the telescope. The scientific gave place to the artistic. For such departure I plead merciful consideration from my scientific friends.

In the plaster casts made from the original, many of the finer details have been lost. As a light fall of snow on rough ground spreads a brilliant blanket, while leaving still the form of every stone and every hummock, so in the casting, the plaster obliterated the harshness of the model, softening all to a pleasing degree. A realistic telescopic appearance resulted, which in some respects compensated for the loss of details obtained only after much labor. By a careful application of a coat of paint of a bluish gray tint the maria, or seas, were given a sufficient contrast from the snow-white plaster mountains to form in all an ideal full moon.

A very interesting question appeared while calculating measurements, "What is the smallest possible discernible object on the moon? Could you see a man there? Would a big tree show?" The average human eye is credited with a power of appreciating an angle of about half a minute of arc. This, however, is quite unintelligible to most people. Let us simplify it. It means that you should see an object one inch in diameter at a distance of about five hundred and fifty-five feet. This would indicate that a "beauty plaster" of one-eighth-inch diameter upon the fair cheek of the debutante should be visible at some sixty-nine feet. Applied to the moon, which averages in size thirty minutes of arc, the unaided eye is capable of discerning a spot measuring one sixtieth of her diameter, or 30 seconds. Now a linear mile on the moon corresponds to 0.87 of a second. Therefore a region one mile square must be magnified by artificial means to equal 30 seconds, that the eye may even perceive it as a point. The power required is evidently about thirty-four. Measurements show that a second of arc represents about two thousand yards on the moon. Thus we would have to magnify an object of that size thirty times to bring it to discernible proportions. Two hundred yards would require ten times this power, or 300. Consequently 20 yards would demand a magnifying power of 3,000! There must be a very fine atmosphere to admit of the use of a power of 500. One thousand power is quite the limit. Even this latter magnification would bring the moon to a distance of 240 miles, and no object under sixty yards could possibly be detected, if our theory is sound. It is quite evident that a man could not be seen. A big tree would not show. Aided by the most powerful telescope, and under conditions of magnification verging upon impracticability, it would be doubtful if an object less than one hundred yards in diameter would be discernible to the human eye as anything but a mere speck. With but one hundred miles separating you from a mountain and with ideal atmospheric conditions, judge what little your naked eye could determine of the details.

Melting Points in Commercial Brasses and Bronzes

As the result of tests made under the direction of the United States Bureau of Mines, the following table of the melting-points of commercial brasses and bronzes has been summarized:

Alloy.	Approximate Composition.				Melting-point.	
	Copper.	Zinc.	Tin.	Lead.	C. deg.	F. deg.
Gun-metal	88	2	10	..	995	1825
Leaded gun-metal....	85½	2	9½	3	980	1795
Red brass.....	85	5	5	5	970	1780
Low-grade red brass	82	10	3	5	980	1795
Leaded bronze.....	80	..	10	10	945	1735
Bronze with zinc...	85	5	10	..	980	1795
Half-yellow, half-red	75	20	2	3	920	1690
Cast yellow brass...	67	31	..	2	895	1645
Naval brass.....	61½	37	1½	..	855	1570
Manganese bronze...	..	..	..	..	870	1600

The melting-point given is the "liquidus," or point where the alloy is completely molten. The tests are described in detail in Technical Paper No. 60.—*American Machinist*.