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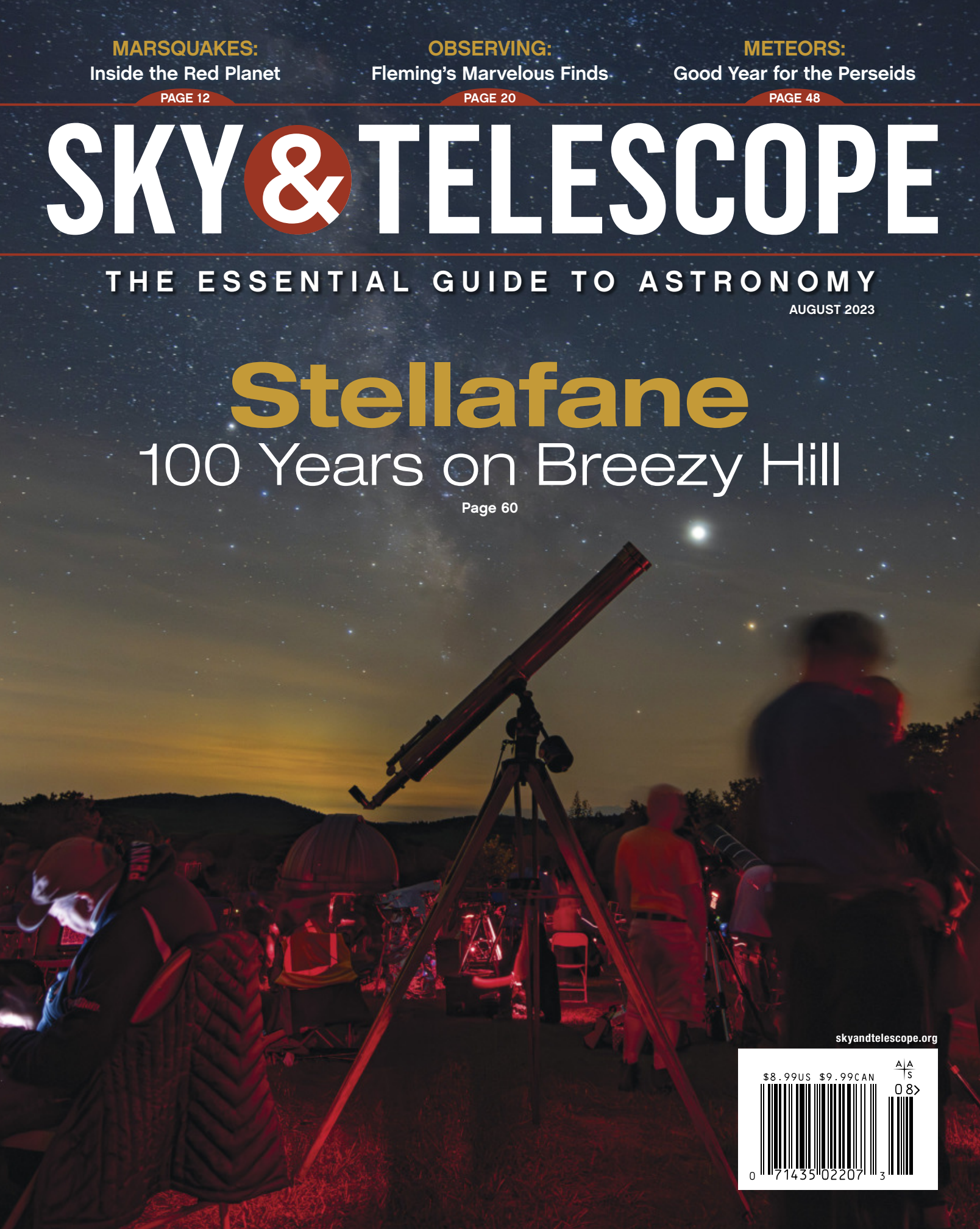

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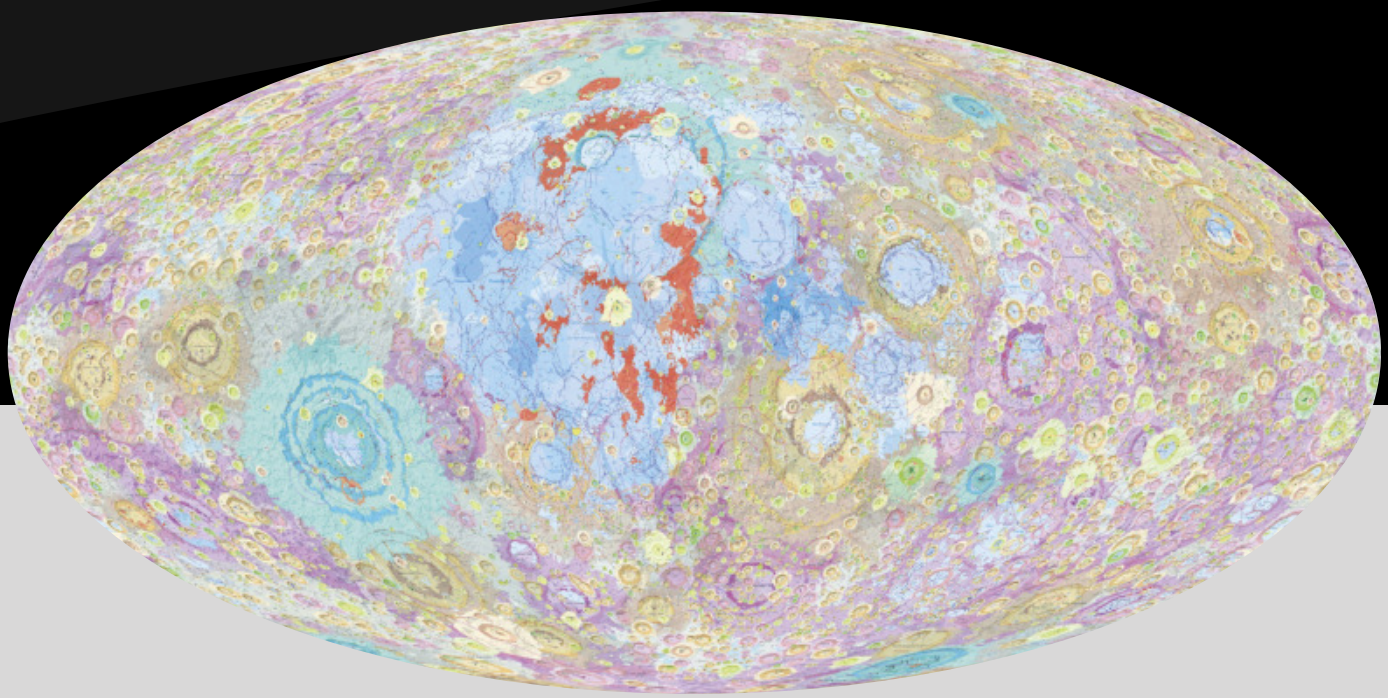


Mapping the Geologic Moon

New resources can enhance your lunar understanding.

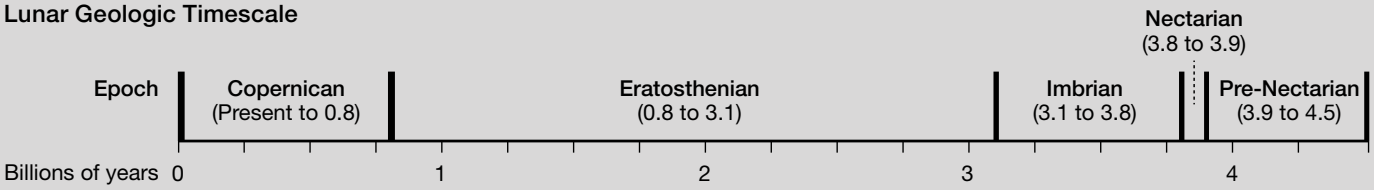
The Moon was always considered an astronomical object. After all, it's located in the sky and is best observed at night. But when, in 1962, President John F. Kennedy decided that Americans should go to the Moon by the end of the decade, it then became a geologic object. For astronauts to land on the Moon and safely return, it was necessary to know the nature and likely condition of the lunar surface. This is what geologists traditionally do — they identify the composition of the terrain as well as its origin and relation to the surrounding materials.

To prepare for the Apollo landings, the task of geological mapping was put into the hands of Eugene Shoemaker, Don Wilhelms, and their colleagues at the United States Geological Survey (USGS). They applied the fundamental terrestrial mapping concept of *stratigraphy* (how the relative position of strata relates to a terrain's age) to the Moon to determine the relative ages of surface materials. For example, the impact crater **Copernicus** provides an easy example of lunar stratigraphy — the crater and its rays sit on top of older materials. Using superposition relationships as well as other methods to determine the freshness of landforms, USGS scientists mapped the geology of the entire lunar nearside by 1971. They were mostly right in determining that maria are volcanic lava flows and bright, highly cratered terrain is much older and includes a great deal of fractured material produced during the formation of countless impact craters.

Amateur astronomers often are most interested in individual landforms, such as craters, mountains, domes, rilles, and mare ridges. And some have adopted the USGS geologic maps in order to better understand the temporal relationship of these landforms. The USGS system divides the lunar surface into five stratigraphic units, from youngest to oldest (see below). These maps have been easy to access since 2020, when the organization compiled its 1970s lunar charts into a Unified Global Geologic Map of the Moon. This map was updated in a variety of ways and, like its predecessors, has become the most widely used lunar geologic map.

Now there's another excellent resource. Beginning with the success of the Chang'e 1 spacecraft placed in orbit in 2007, the Chinese Lunar Exploration Program has grown to include probes, rovers, sample returns, and

Lunar Geologic Timescale



GEOLOGIC MAP OF THE MOON: JINZHU JI ET AL. / INSTITUTE OF GEOCHEMISTRY / CHINESE ACADEMY OF SCIENCES / CC BY 4.0; LUNAR GEOLOGIC TIMESCALE: TERRI DUBÉ / S&T

◀▲ The USGS Unified Geologic Map of the Moon (above) and the new, larger-scale Chinese geologic map (facing page)

even plans for human exploration in the next decade. To support these missions, the Chinese Academy of Sciences has produced a large-scale map (fortunately in English) that contains even more information than the USGS map. The Chinese map is sourced from the nation's own lunar exploration program as well as from data provided by the U.S., Japan, and India lunar missions.

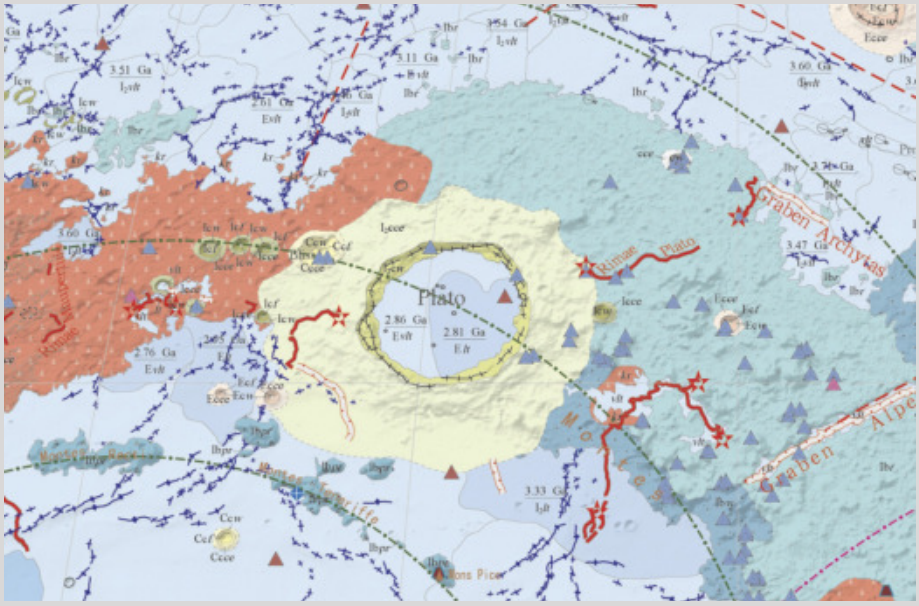
The most obvious difference between the two maps is the color scheme. The USGS map uses mostly saturated colors: Maria are shaded red, while impact craters of different ages are of various other bright colors. Young craters, such as Copernicus and others that formed in the last 800 million years, are colored yellow, and craters older than about 3.8 billion years, including **Ptolemaeus**, are tinted brown. The Chinese map color-codes geological differences with subdued pastels — all the better to read data and names on the map. Still, the Chinese map looks very much like the USGS one in that both accurately depict the same Moon. Perhaps as an homage to Earth's oceans, the lunar maria on the Chinese map are blue.

The real differences between the maps lie in the details included and how they are depicted. Both show craters and their floors, their rims and ejecta fields, mare ridges, rills, and mountains. But the Chinese map displays more of all these features in better detail. For example, impact basins are depicted with inner rims and multiple outer rings, differing from the way they've been depicted in the past. This shows our understanding of complex features is still evolving.

The Chinese map also displays the ages of maria (based on the work of Harold Hiesinger and colleagues at the University of Münster) with five shades of blue indicating different compositions of basalts, from very low to very high titanium levels. A glance at the lavas in **Mare Imbrium** reveals that the ones with flow fronts that erupted from the basin's western rim area are 2.3 billion years old with a medium titanium composition, and the surrounding lavas are about a billion years older and contain a low titanium content. I'm not aware of any other place where such information is so readily available.

The good news for observers is that both maps are freely available for download at **https://is.gd/USGS_Moon** and **https://is.gd/CN_Moon**; the files are a few hundred megabytes in size but worth the wait. Don't try looking at them on a mobile phone; they deserve large screens. And while both the USGS and Chinese maps are digital versions of traditional paper maps, the revised USGS map is included on the Lunar Reconnaissance Orbiter QuickMap site at **https://is.gd/USGSmap**. You can use this site to compare its data to gravity data, topographic data, and many other geologic data sets superposed on top of high-resolution LRO mosaics.

■ Contributing Editor **CHUCK WOOD** will be spending many evenings pouring over these new maps.



▲ This detail of the Chinese map shows Plato and surrounding regions, including multiple outer basin rings as well as mare ages and compositions.

USGS UNIFIED GEOLOGIC MAP OF THE MOON; UNITED STATES GEOLOGICAL SURVEY / ASTROGEOLOGY SCIENCE CENTER / WILHELMS, D.E. ET AL.; MAP DETAIL: JINZHU JI ET AL. / INSTITUTE OF GEOCHEMISTRY / CHINESE ACADEMY OF SCIENCES / CC BY 4.0