Transcript: Rocks in His Head

Hi this is Steve Nerlich from Cheap Astronomy www.cheapastro.com and this is *Rocks in His Head.*

Gene Shoemaker was a lunar geologist long before he started getting comets named after him. When the US Center of Astrogeology was founded in 1965, Shoemaker was appointed its chief scientist and in this role he outlined the geological activities that should be undertaken in the Apollo Moon landings. He also taught geology to astronauts in line to fly to the Moon – a role later taken up by geologist Lee Silver for the extended Apollo 15 – 17 missions. Shoemaker had even hoped to be the first geologist on the Moon, but this plan was cut short by a diagnosis of Addison's disease in 1962- which prevented him from ever going into space.

In July 1969, Shoemaker's plans began to unfold as the lunar module crew of Apollo 11 touched down and scrambled about for less than 2 hours grabbing a few rocks before flying home.

Apollo 11 landed in the Sea of Tranquility. There's a map linked to this episode at Cheap Astronomy's podcast page which will show all the Moon's features and the Apollo landing sites I'm going to mention.

The Apollo 11 samples were rocks and also moon dust, often called regolith. Regolith has the consistency of talcum powder, makes excellent footprint impressions and is really just pulverised rock arising from repeated meteor strikes on the Moon's surface.

The Apollo 11 samples confirmed that the Sea of Tranquility was a great plain of basalt about 3.5 billion years old. This was interesting since a) it confirmed the Sea of Tranquility was a big flat pool of cooled lava, which had been the popular prevailing theory and b) it meant the Moon was more than 3.5 billion years old, which had not been the popular prevailing theory.

Apollo 12 landed in the Ocean of Storms, the biggest of the grey splotches you can see on the Moon's face. Apollo 12 collected not only surface rocks, but also the first drill core from the Moon. Not altogether unexpectedly the drill core sample was basalt, but from a lava flow that had formed a good half billion years after the Sea of Tranquility.

This was consistent with the Apollo 12 astronauts noting the regolith was shallower at their site and that all their rocks had less *zap pits* – tiny holes caused by micrometeorites not much bigger than a sand grain – a phenomena completely unknown on Earth as such things just burn up in our atmosphere.

Like all the rocks found at the Sea of Tranquility, the Apollo 12 samples were free of what are called volatiles, things with a low boiling point – including water, hydrogen, nitrogen and even carbon and sodium. While this was consistent with the formation of basalt in a vacuum, it was a bit odd that every single rock they collected, whether basalt or not, was like this. It was as though every part of the Moon had been cooked at high temperature for an extended period.

Apollo 13 never landed and the astronauts where otherwise occupied with saving their lives, but this mission still delivered some good science. The 3rd stage of their Saturn V

rocket was deliberately crashed onto the Moon about 44 km from a seismometer placed by Apollo 12. The lunar crust reverberated from the impact for nearly 4 hours. Analysis of the shock waves confirmed that the Moon's crust was solid, heavily fractured, rock – down to a depth of at least 100 km, suggesting that the inside of the Moon had experienced no recent geological activity, apart from a seemingly non-stop bombardment of meteors.

Apollo 14 landed in the region Apollo 13 had planned to, which was close to the Apollo 12 site, but with a lot of debris lying around which was thought might include deeper rocks blown out from nearby Copernicus crater.

What they found was a lot more basalt and breccia being a compressed rock of disassociated minerals that were suddenly jammed together by the shock wave of a meteor impact – a phenomena already familiar to Gene Shoemaker from his studies of Meteor Crater in Arizona. It was becoming clear that lunar geology had a lot to do with meteor impacts.

Apollo 15 visited the Apennine mountains. Their most significant find was the Genesis Rock made of anorthosite that had probably fallen from the lunar highlands. Anorthosite is one of a group of minerals which are the scum that accumulates on the surface of, say, an ocean of magma – which then becomes surface rock when that ocean cools.

It also began to become clear that all moon rocks were not only free of volatiles, but also KREEPy. That is, rich in potassium (K), rare earth elements (REE) and phosphorus (P). These KREEPy, seemingly incompatible, elements could only become involved in mineral crystallization if formed in an extended liquid state – like, say, in an ocean of magma.

Apollo 16 was the great null hypothesis. Expecting to prove a volcanic origin to the Apennine mountains, they instead discovered that these mountains (some as high as four kilometres) were just an uplifted dividing edge between two giant impact craters.

Apollo 17 launched with Harrison Schmidt playing the role Gene Shoemaker had hoped for, the first trained geologist on the Moon. It's actually the case that most minerals collected in Apollo 17, and earlier missions, were present in the Apollo 11 samples – since the ejecta of meteor collisions spreads everything around on the Moon's surface. But, as any geologist would tell you, you need context. It was the discovery of particular minerals in particular locations that really pulled the whole story together.

The accumulated evidence of the Apollo samples, samples returned by the Russian Luna 16, 20 and 24 missions and a few lunar meteorites found on Earth, suggests the Moon began its life as a ball of molten rock, which cooled and then did little else geologically, apart from being hit by meteors, large and small, for 3-4 billion years.

All those dark grey Seas of the Moon visible to the naked eye are really giant impact craters, some up to a 100 kilometres deep, that were subsequently filled by pools of lava when the Moon still had a molten interior. Samples from these Seas have higher levels of iron and titanium, probably a result of those lava flows bringing heavier elements from the Moon's core up to the surface.

All this is consistent with the Big Splat hypothesis – where a since-obliterated Mars-sized

object named Theia, collided with a proto-Earth about 4.5 billion years ago, creating a whole new Earth surrounded by a huge cloud of molten debris which then collapsed down into a huge orbiting Moon, more than a quarter of the size of its planet.

Gene Shoemaker died in 1997 after putting his name to the biggest celestial impact ever televised, being the collision of the comet Shoemaker-Levy 9 with Jupiter in July 1994. He is considered to be the first person ever buried on the Moon – when some of his ashes were sent there aboard the Lunar Prospector spacecraft which was deliberately crashed near the south pole of the Moon on the 31st of July 1999.

Thanks for listening. This is Steve Nerlich from Cheap Astronomy, www.cheapastro.com. Cheap Astronomy offers an educational website that puts the economy back in astronomy. No ads, no profit, just good science. Bye.