Resources for learning about the geology of Venus

Summary of the Geology of Venus from NASA and JPL
http://www2.jpl.nasa.gov/magellan/guide3.html

Doing Planetary Geology on Venus!! An in-class and at-home exercise!
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http://www.cas.usf.edu/~jryan/Venusactivity.html

It's a Dry Heat: The Geology of Venus from Magellan
Compiled by Robert R. Herrick and Maribeth H. Price
http://www.lpi.usra.edu/publications/slidesets/venus/index.shtml and
http://www.lpi.usra.edu/publications/slidesets/venus/venus_index.shtml

Geology of Venus

by Fraser Cain on July 28, 2009
http://www.universetoday.com/36158/geology-of-venus/

Artistic interpretation of a possible volcano on Venus. Credits: ESA - AOES Medialab

Take a look at Venus in even the most powerful telescope, and all you'll see is clouds. There are no surface features visible at all. It wasn't until the last few decades, when radar equipped spacecraft arrived at Venus, that scientists finally had a chance to study the geology of Venus in great detail.

Spacecraft like NASA's Magellan mission are equipped with radar instruments that let it penetrate down through the clouds on Venus and reveal the surface below. Magellan found that the surface of Venus does have many impact craters and evidence of past volcanism. But the total number of craters showed that the surface of Venus is actually pretty young. It's likely that some catastrophic event resurfaced Venus about 300-500 million years ago, wiping out old craters and volcanoes.

Unlike Earth, Venus doesn't have plate tectonics. It's possible that the planet had them in the ancient past, but rising temperatures shut them down and helped the planet go into a runaway greenhouse cycle. Carbon on Earth is trapped by plants, and is then recycled into the Earth through plate tectonics. But on Venus, the tectonic system shut down, so carbon was able to build up to tremendous levels. This cycle thickened the atmosphere, raised temperatures with its greenhouse effect, releasing more carbon, raising temperatures even higher… etc.

There are volcanoes on Venus; scientists have identified more than 100 isolated shield volcanoes. And there are thousands and maybe even millions of smaller volcanoes less than 20 km across. Many of these have a strange dome-shaped structure, believed to have formed when plumes of magma thrust the crust upward and then collapsed.

Scientists can't be exactly sure what the internal structure of Venus is like, but based on its density, Venus is probably similar to Earth in composition. It's believed to have a solid or liquid core of metal 3,000 km across. This is surrounded by a mantle of rock 3,000 km thick, and then a thin crust of solid rock about 50 km thick.

One big difference between Earth and Venus is the lack of a planetary magnetic field at Venus. It's believed that the Earth's magnetic field is driven by the convection of liquid metal at the Earth's core. If true, it means that Venus probably doesn't have the same kind of temperature differences at its core, and lacks the convection to sustain a planetary magnetic field.

We have written many articles about Venus for Universe Today. Here's an article about Venus' wet, volcanic past, and here's an article about how Venus might have had continents and oceans in the ancient past.

Want more information on Venus? Here's a link to Hubblesite's News Releases about Venus, and here's NASA's Solar System Exploration Guide to Venus. We have recorded a whole episode of Astronomy Cast that's only about planet Venus. Listen to it here, Episode 50: Venus.

Reference:
NASA Solar System Exploration: Geologic Landforms of Venus
NASA Science: Blazing Venus
NASA Solar System Exploration: Venus

The Baffling Geology of Venus

By Andrew Alden

http://geology.about.com/od/venus/a/aa_venus.htm

Venus has always been mysterious. The earliest observers had two names for it, the Morning Star and the Evening Star. Telescopes showed only a disk of brilliant white, thick clouds hiding all trace of a surface beneath. More recently radar mappers, the Russian landers and other spacecraft studies have lifted Venus's veil to science, but today it remains mysterious.

Venus is almost a twin of Earth in terms of size, mass and composition. It's only slightly smaller, formed in the same neighborhood of the solar system, and has a large iron core and rocky silicate mantle. Like Earth, its crust is largely basalt (though on Earth the basalt is almost all hidden by the ocean).

The Role of Heat in Venus Geology

The key to the geology of Venus seems to be its heat. Start with its thick, choking atmosphere of nearly pure carbon dioxide. Air pressure on Venus's surface is about 90 times Earth's, the same as it would be a full kilometer under the ocean. This greenhouse gas is so effective at trapping the sun's heat that the ground of Venus is literally hot as a furnace, reaching around 450 degrees C (or 725 K) at the equator, year round. There is no water anywhere except a little high in the atmosphere. The white clouds are composed of sulfuric acid droplets.

The crust of Venus appears to be almost entirely volcanic and basaltic. There is nothing there like Earth's continents—no granitic rocks at all, high in silicon and oxygen (except possibly the high plateau called Ishtar Terra). Venus instead has large, bizarre fractured structures called coronae ("crowns") and tesserae ("mosaic chips"). There is no large-scale motion of the crust, no plate tectonics. On Earth, plate tectonics is driven by surface cooling, which makes the cold plates denser than the soft rock layer beneath them. On Venus the surface cannot cool and the crust cannot overturn.

Nevertheless, the presence of lava everywhere we look on Venus means that deep heat from the underlying mantle and core can melt rocks and cause that magma to erupt. The eruptions appear random, unlike the organized lines and arcs of volcanoes on Earth. Is this all that ever happens? The way to answer that question is to study the geologic history of the planet in detail.

Venus's Geologic History

The backbone of planetary dating is crater counts. We have a good idea, from studying the other planets, of how old a surface is based on the number of craters it has. On all of Venus there are about 1000 craters, an unusually small number. The crater statistics tell us that although the planet is 4.6 billion years old, nothing on its surface is older than roughly 0.5 billion years. Almost all of Venus's history is a blank slate.

It looks as if half a billion years ago, all of Venus's surface was replaced. Within perhaps one-tenth that time, maybe 50 million years, almost all of the features we see were emplaced: highly deformed tesserae first, then large plains of lava heavily wrinkled in huge ridges. The lava flows that have occurred since that early period are fairly smooth and undisturbed. It is the picture of a thin, soft crust quickly growing harder and thicker as the mantle roiled beneath it. That's one working hypothesis.

It's easy to picture a gigantic planetary cycle in which Venus "boils over" and replaces its surface with a new lava crust. It's harder to prove such a model, or to say how fast it happens. Only with more information can we make progress. But there are no plans yet to return to Venus's surface (Venus Express, which arrived at Venus in 2006, and Planet-C, which failed to orbit Venus in December 2010, are both orbiter missions). For now we must work with the data we have—plus powerful computer simulations. Those suggest that Venus's wrinkled face may be due to hot flashes from above and below, as I explain next.

The radar mapping of Venus's surface has laid bare its mysterious wrinkled crust and given us hints about the mantle beneath. We also have a bit of insight into the iron core from the planet's magnetic field—that is, from its absence. No magnetic field means the core is not stirring. For stirring, or convection, to occur there must be heat below and cold above, just like the pot of water boiling on your stove. But Venus is hot all the way up to the surface.

Moreover, Venus may not have a solid inner core as Earth does. On Earth, energy is released as iron freezes onto the inner core, stirring the liquid metal above it. If Venus lacks this source of heat below and is not strongly cooled from above, then its core must be too sluggish to generate a magnetic field.

Earth's geomagnetic field protects us from a great deal of high-energy radiation from the sun. On Venus, all of that same radiation—more of it, actually, since the sun is closer—slams onto the atmosphere. In fact the more we study Venus, using computer simulations, the more the atmosphere matters. It is a most unusual greenhouse.

The Deep Venus Greenhouse

Carbon dioxide (CO_2) makes up 96 percent of Venus's dense atmosphere, retaining so much of the sun's energy that any ocean the planet once had was long ago boiled away. But two trace gases, water vapor and sulfur dioxide, have powerful effects too. The reason is that CO_2 isn't a perfect greenhouse—it allows certain wavelengths of radiation through. Water vapor and sulfur gases plug those holes. These two gases are released during volcanic eruptions, and if there are enough eruptions Venus gets a really bad fever.

These volcanic gases are removed from the atmosphere over millions of years. Water vapor breaks down under the intense solar radiation into oxygen and hydrogen, and the hydrogen escapes into space. That's how Venus lost its water ages ago. The sulfur gases react with the rocks on Venus's surface and leave the atmosphere from the bottom. But until these processes are finished the temperature rises significantly, 100 degrees or more. After a few million years the extra heat penetrates the crust to the upper mantle, bringing it closer than ever to melting. This feedback encourages more eruptions.

Researchers look at the massive eruptions of 500 million years ago, which resurfaced the whole planet, and ask what the volcanic gases from that cataclysm did. Their models suggest that the pulse of greenhouse heat actually expanded the crust, warping it to create the wrinkle ridges covering most of the surface. As the atmosphere cooled, the crust shrank to open cracks elsewhere on Venus. Smaller eruptions have similar but lesser effects.

Venus's Crustal Turnover

One might ask next how such a big crustal turnover happened. As with other planetary puzzles there are two possible causes, one from below and one from above. On Earth, the largest continental plates tend to trap heat beneath them, eventually causing them to break up. If Venus is considered a "one-plate planet," then such a breakup from below could start with one large eruption. Reinforced by atmospheric feedback, the disturbance would spread to affect everything at once.

The alternative is that fresh greenhouse gases enter the atmosphere from above, from large comets. Simulations suggest that comet collisions would deposit water vapor without blasting the atmosphere away. Under that water vapor blanket, the rocks of Venus would roast and soften to the melting point, just as when heat builds up below. Either way, this strange world would give birth to its new face.

Is Venus Active?

Recent results from the Venus Express mission suggest an alternative to this picture. Researchers took a close look at several high mountains that, at least in their shapes, resemble large shields like the Hawaiian chain of volcanoes. Hawaii is considered the type example of a hotspot, and so it's natural to look for the same on Venus.

The way these high volcanoes interact with infrared light—their emissivity, to be exact—suggests that at their tops are fresh rocks. (See this explanation from the Venus Express site.) Given the chemistry that we expect between fresh basalt lava and the active atmosphere of Venus, and assuming a model of Venus in which volcanic resurfacing is constant rather than episodic, these rocks could be younger than a quarter-million years and possibly brand-new. That is a lot of assumptions, but when data is scant that's all you can do. The evidence for young lava is good, but is there enough of it to make it the rule or the exception? The answer is not yet nailed down.

PS: Early in the history of the solar system, Venus may well have contained oceans and a CO_2-nitrogen atmosphere like just that of the early Earth. Thus life may have arisen there once. It's even conceivable that cosmic impacts carried pieces of Venus to our planet. After all, earthly meteorites include pieces of Mars.