Image: Jared Sluyter

The Science of Clay

What is clay, and what can it tell us about our environment? Does it hold the secrets of life on Mars?

This resource comes from arts organisation Clayground Collective's research into the properties and creative potential of clay. It is intended to inform cross-curricular work with clay, from the studio to the science lab and beyond school.

It was developed with Clay Geochemistry Researcher Dr Javier Cuadros in partnership with the Crafts Council. Javier investigates clay geochemistry and processes in all environments. His research covers clay on Earth and elsewhere in the Solar System, clay-life interaction, what clay can tell us about environments in the past, and the crystal-chemistry of clays.

What makes a clay?

◊ Clays are a group of minerals distinguished by their small particle size, composition and crystal structure.

◊ Technically, clays are termed hydrous phyllosilicates:

- 'hydrous' means they contain water;
- 'phyllo' because they have a sheet-like structure (from 'phyllo', which means leaf);
- 'silicates' because they are based on silicon

◊ Clays are classified in several groups, of which the most common are: kaolin, smectite, illite, and chlorite. Montmorillonite is from the smectite group. Bentonite is a rock of volcanic origin containing a very high proportion of smectite.

◊ Clay's main ingredients are Silicon, Aluminium, Magnesium, Iron and Oxygen. Clay's mineral content is determined by its specific geological origin and varies according to location.

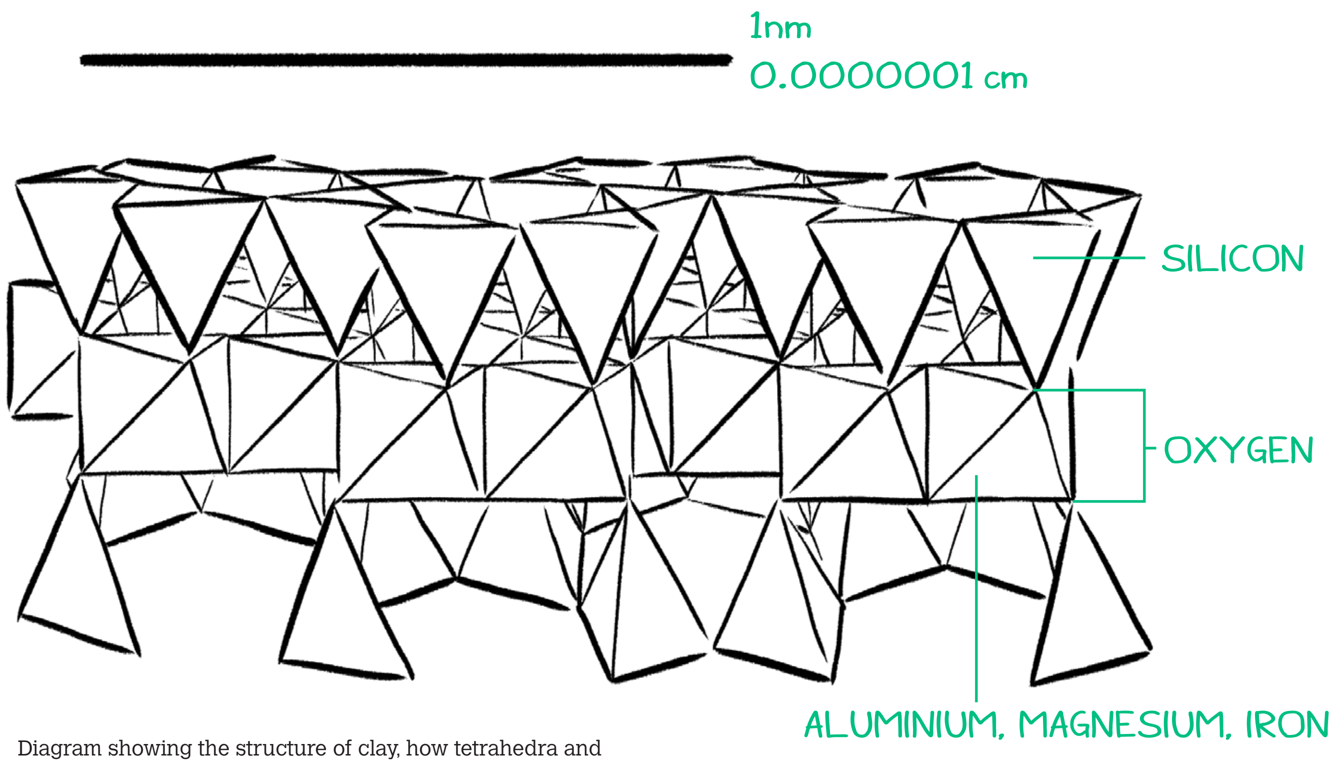


Diagram showing the structure of clay, how tetrahedra and octahedra are arranged in sheets, and where the different atoms are located in the structure.

Clay: Wonder Material!

Clay with Diatom. Magnification 8000X, hand coloured SEM micrograph, Rob Kesseler, Clayground Commission, 2014

◊ The properties of clay are amazingly varied: clay is resistant to heat, absorbs water, and is thixotropic (can turn from a liquid to a solid and back again). These properties mean clay is a useful ingredient in medicines, cosmetics, and can be used to make domestic items, line canals and reservoirs, and in industrial processes from paper production to mining.

◊ Plasticity means how easy a clay is to work with and mould, its softness and malleability. Clay's plasticity is determined by several factors: small particle size, how much water it contains, and its sheet-like structure, which allows the sliding of sheets and plate-like particles. Clay's texture changes most visibly according to the quantity of water it contains. As it moves from wet to dry, it resembles the qualities of other materials including paint, leather, cloth, pastry, wood and stone. Both artists and scientists work with these changing qualities.

◊ All these properties are determined by the fact that clay is a mineral made of small, loose particles that can be shaped, applied as a layer onto other materials, dispersed in liquids, or hardened by firing.

Clay's origins and relation to life

◊ Microorganisms are often found in clay. Some are thought to have an effect on its plasticity, similar to yeast in baking. This may account for potters' folk wisdom that if clay is left to 'cure' for some time, its plasticity improves.

◊ Clay supports life on Earth. It provides physical support to plants and holds water, which in turn retains nutrients to support growth. Clay itself can also retain nutrients that can be retrieved as needed by plants and microorganisms.

◊ Legends around the world claim that life itself emerged from clay. These include the Jewish tradition of the Golem (an anthropomorphic being made of clay or mud), the Greek god Prometheus, who was believed to have created humans from clay, and the Sumerian god Enki.

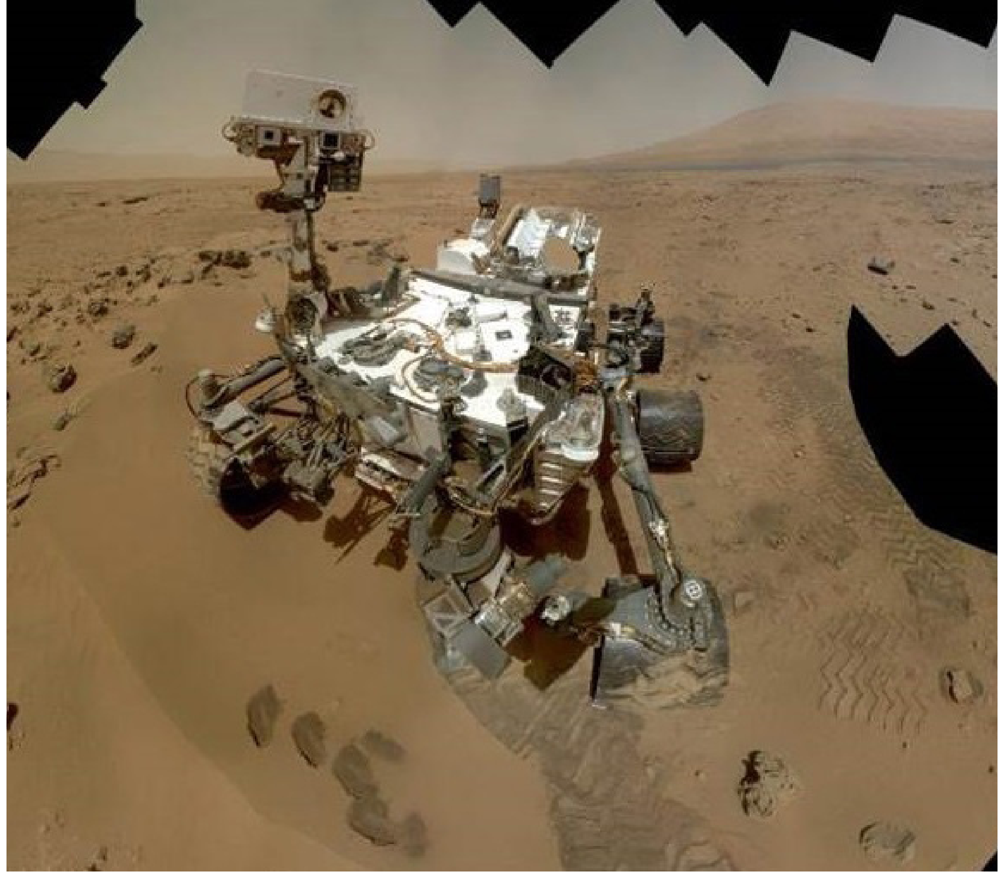
◊ Scientific findings point towards clay playing an important role in the emergence of life. Clay may have concentrated small organic molecules essential for life and fostered their condensation to generate large molecules such as RNA, DNA, and proteins. These molecules would have been primitive predecessors to those that developed fully in living organisms.

Image: L. John Hill Wikimedia Commons; R. Javier Cuadros

◊ Clay is formed over thousands of years as rocks and volcanic lava are broken down by the effects of water, weather and interaction with micro-organisms. High temperatures speed up the formation process.

Left: Cross section through soil with a clay-rich layer at the bottom in ochre. Image Rodney Burton
Middle: Clay pit at Saltwells, Dudley, UK, where ceramic industrialist Henry Doulton quarried raw material. Near the top of the quarry you can see a black line of coal. Photos: Caroline Gervay and Rodney Burton
Right: Saltwells clay sample with Testate amoeba soil protozoa with protective shell of silica soil particles. Protozoa play an important role in the structure of the soil food web. Magnification 8100x Hand coloured SEM micrograph. Rob Kesseler 2014.

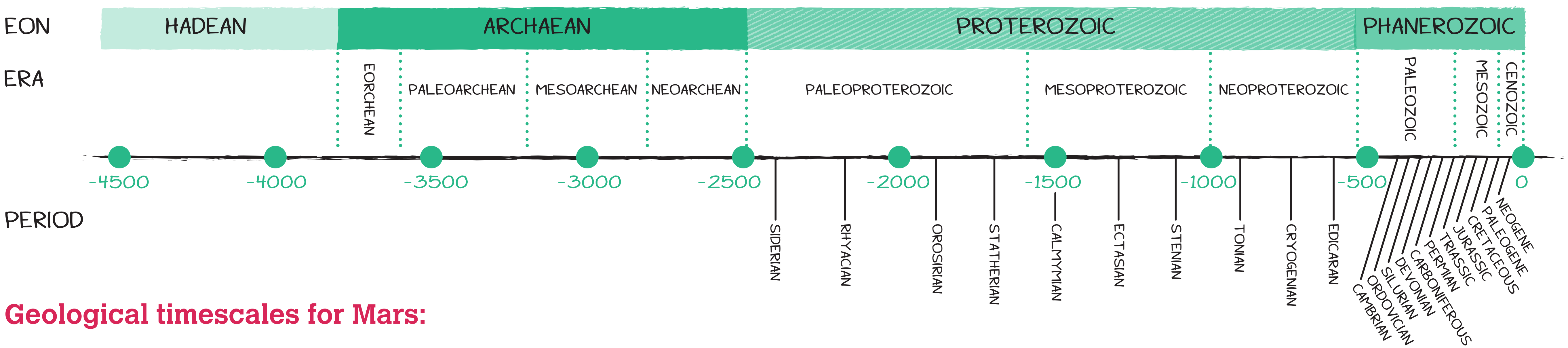
Clay in Space



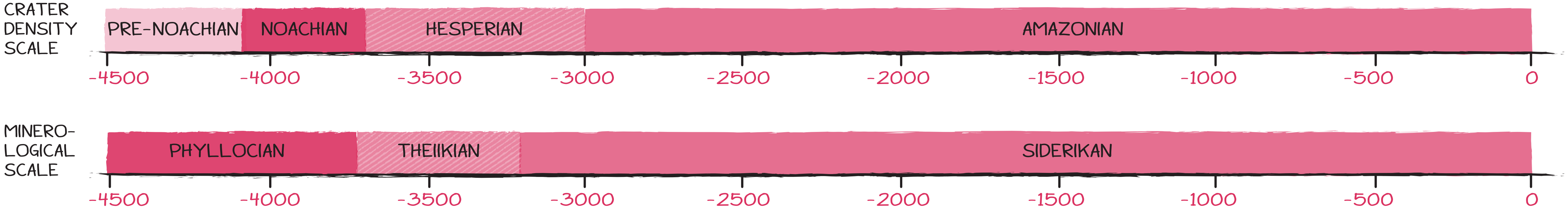
Self-portrait photo-montage of Curiosity in Gale Crater, Mars. Photo by NASA.

- Clay is also found on other planets in the solar system and in meteorites arriving on Earth from space. The NASA Rover, Curiosity, travelled to Mars in 2012 and was deliberately landed in an area of high clay content.
- As clay can only be created through the action of water, the presence of clay on Mars indicates that water once existed on the surface of Mars, and that the planet may once have had the potential to support life. Clay is a likely material where traces of life may have been preserved, protected beneath the surface from the harsh Martian atmosphere.
- Investigating clay on Mars allows us to learn more about the history of Earth. Scientists have established that there are no tectonic movements on Mars. These movements on Earth have obliterated ancient rocks and erased geological clues to Earth's early history. Through infrared spectroscopic investigation from satellites we know the make-up of clays on Mars, how and when they formed and can compare the resulting geological history with that of our own planet.

Geological timescales for the Earth:



Geological timescales for Mars:



Two scales are shown for Mars, one based on the age of the rocks, from crater density, and one based on the most abundant minerals formed. Phyllocian stands for the period of phyllosilicates (clays). (Modified from Wikipedia.)

Electric industrial kiln at Middleport Pottery, Stoke

Making Clay into Ceramics

- ◊ As soon as clay is fired it is called 'ceramic'.
- ◊ Clay is usually fired to between 800-1200°C. The higher the firing, the harder the finished product, but each clay has a melting point at which it will bubble and collapse. In order to harden, clay needs to contain minerals other than clay, called 'degreasers'.
- ◊ The terms 'earthenware' and 'stoneware' refer to the temperature at which clay is fired. Earthenware is usually fired up to 1180°C. Anything fired above this temperature is called Stoneware.
- ◊ At 573°C clay changes into a stone-like material. This process is called quartz inversion. At any time before this temperature is reached, clay can be reclaimed through soaking in water and drying. After this temperature, it can also be reclaimed— but the process will take thousands of years!
- ◊ Potters today usually fire clay twice. The first firing, at around 800°C, is called the 'btisque' firing. It is then often covered in a glass-like material or glaze and fired a second time at higher temperatures (around 1200°C), called the glaze firing.

Left: Paper kiln in which clay items are surrounded with wood encased in layers of clay-soaked paper
Middle: Kiln in a shopping trolley using paper kiln technique
Right: Brick-built up draft kiln in which clay items are fired in a chamber above the fire

Uses for Clay

Animals and Clay

- ◊ Rainforest birds such as macaws visit layers of clay inn cliffs and riverbeds to eat clay. This is to aid digestion and sometimes to counteract the toxic coverings of the seeds they rely on for food.
- ◊ Monkeys, peccaries (a kind of pig) and other fauna, eat clay to obtain the trace minerals needed to remain healthy.
- ◊ Potter wasps are found in temperate regions of the northern hemisphere. The female carries little perfectly round balls of clay in her mouth to create an even-walled, vase-shaped nest.

Clay in Industrial Processes

- ◊ Clay is used in water filtration, clarification of wine, paint production, leather tanning and rubber manufacture.
- ◊ Clay is the main element of catalytic converters filtering noxious emissions from cars.
- ◊ Crucibles are made of ceramic allowing metals to be melted at very high temperatures.
- ◊ Ceramics are used for spark plugs and electrical insulators.
- ◊ Clay's properties as a natural sealant mean it is virtually impermeable to water once saturated. It is used at the cores of dams, to line canals and tunnels, in landfills to prevent toxic seepage and to store nuclear waste.

Medicinal Uses

- ◊ Clay is used in medicines like Kaolin and Morphine to relieve the symptoms of diarrhoea. Some ancient cultures knew about clay's medicinal properties and ate it raw or fired.
- ◊ Indigenous peoples in Africa and South America have used specific naturally occurring clays for centuries to treat wounds and external ulcers. These clays help healing and protect from infection. Not all clays have these properties and scientists do not yet know what causes the beneficial effects.

Uses for Clay

Clay Everyday

- Clay is commonly used in bathrooms and kitchens: toilets, sinks and tiles are made of ceramics, making them durable and easy to clean. Ceramic knives, frying pans and hobs are common.
- Toothpaste, cosmetic products like foundation and powders, and deodorant all contain clay.
- Clay face-masks have been used throughout history to clarify the skin.
- Celebrity culture depends on clay! The pages of glossy magazines are covered in a thin layer of clay. Its absorbent properties soak up the colouredt ink and reflect the images from a smooth surface. The glossier the page, the higher the clay content.

This resource was prepared by Clayground Collective with Javier Cuadros, in partnership with the Crafts Council as part of Make Your Future.
For more information, and more resources to support craft in the classroom visit www.craftscouncil.org.uk

To receive news of Clayground Collective's forthcoming book Clay in Common (2018) Triarchy Press, about clay and creative projects in and out of school please register at www.claygroundcollective.org

We'd love to know how you use this resource with your students. Get in touch:

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