What are four causes of weathering? Weathering is the breakdown of rocks, and it is usually broken down into two general categories: physical and chemical weathering. Within those two categories, there are many specific causes of weathering of rocks. Freezing and thawing, acid rain, root wedging, and temperature and pressure changes are four examples of causes of weathering of rocks. Keep in mind that none of these forces act in a vacuum in the real world though – the weathering of rocks is often caused by a combination of factors. Physical weathering of rocks causes them to be broken down into smaller fragments, but it does not change the chemical composition of the rocks. Temperature and pressure changes are often the underlying causes of physical weathering. For example, one of the main types of physical weathering, freeze-thaw action, is caused by temperature changes. This type of weathering occurs when water or moisture seeps into the cracks or joints in rocks. When the air temperature drops below freezing, the water in the cracks also freezes, and water expands when it changes from liquid to solid. The expansion of frozen water exerts pressure within the crack or joint, pushing it further apart. This can eventually lead to pieces of rock breaking off the main body of the rock. Pressure and temperature changes can cause the weathering of rocks even when water is not involved. Differential temperatures and pressures within rock outcrops can lead to exfoliation, a process that is also called onion-skin weathering because it leads to the outer layers of rocks falling off. Strata(Sumner'>Chemical weathering/08%3A_Old_or_Lost_Pages/8.07%3A_Weathering_and_Erosion) affects the actual composition of rocks. Some rocks are more prone to chemical weathering because of the unstable minerals they contain, while those that are made up of stable minerals are more resistant to chemical alteration. The process of chemical weathering involves chemical reactions between the minerals in rocks and the minerals in their environment. Minerals in the air and in precipitation can lead to the chemical weathering of rocks. A clear example of this phenomena is acid rain, which is precipitation with an unusually low pH. The chemicals in acid rain react with unstable minerals in some rocks, leading to the dissolution or alteration of the composition of the rocks. Another common type of chemical weathering is oxidation, which is commonly called rusting. Oxidation occurs when unstable minerals in rocks are exposed to atmospheric oxygen; the oxygen interacts with chemicals in some rocks to cause the chemical alteration of the oxidized rocks. It is often the case that the many causes of weathering of rocks work together, creating a synergy of forces that accelerate the breakdown of rocks. For example, the physical weathering of rocks caused by freeze-thaw action exposes more surface area, making rocks more susceptible to chemical weathering. In other cases, biological factors work with chemical or physical forces to speed up the weathering of rocks. One example of this synergy is the interactions between plants and animals with the typical causes of weathering. When an animal digs a burrow and brings rocks to the surface of the Earth, this makes the rocks more vulnerable to both chemical and physical weathering. Or, when a rock joint expands due to changes in temperature and a tree takes root within the crack, biological and physical forces are working together to cause further weathering of the rock. While the causes of weathering may be isolated in the controlled conditions of a lab, there are many uncontrollable variables in real-world conditions. The forces that break rocks down in the real world are often working together to increase the rate of weathering. Sloane, Christina. "List Four Causes Of Weathering" sciencing.com, . 1 December 2021. APA Sloane, Christina. (2021, December 1). List Four Causes Of Weathering. sciencing.com. Retrieved from Chicago Sloane, Christina. List Four Causes Of Weathering last modified August 30, 2022. What are four causes of weathering? Weathering is the breakdown of rocks, and it is usually broken down into two general categories: physical and chemical weathering. Within those two categories, there are many specific causes of weathering of rocks. Freezing and thawing, acid rain, root wedging, and temperature and pressure changes are four examples of causes of weathering of rocks. Keep in mind that none of these forces act in a vacuum in the real world though – the weathering of rocks is often caused by a combination of factors. Physical weathering of rocks causes them to be broken down into smaller fragments, but it does not change the chemical composition of the rocks. 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For example, other rights such as publicity, privacy, or moral rights may limit how you use the material. Prospective Students Page 2 Prospective Students Our physical environment is heavily impacted by extended exposure to the elements of weather and climate. This is known as weathering. We examine this phenomenon, and its impact on the environment.Weathering is defined as the slow and systematic breakdown of stone, soil, and vegetation like wood caused by contact with elements in the atmosphere, such as rain, heat, cold, and wind. Weathering also directly impacts artificial or human-made objects and even the human body, specifically the skin.It slowly takes place on a daily basis and probably right in front of your eyes without you even being aware of it. Weathering is a slow but persistent process, which can result in irreversible damage to both your bodies and the environment. But weathering is not the only culprit. Another process called erosion can also wear down and change the environment over time. However, it must be important to note that weathering and erosion are not the same phenomena. Although they often get confused with each other, weathering and erosion are two entirely different processes. We will highlight these differences later on in this article, as well as how they relate to each other.Before we delve into the details of how and why weathering takes place, as well as its relationship with erosion, we need to define what weathering is in the first place. Weathering is the slow and systematic breakdown of stone, soil, and vegetation like wood as a result of contact with elements in the atmosphere such as rain, heat, cold, and wind. Weathering also impacts artificial (human-made) objects and even our human bodies directly. Sustained periods of exposure to any one of these elements in the atmosphere, or a combination of them, will result in a weakening and eventual breakdown of most objects.The Difference Between Weathering And ErosionSince the causes of weathering include erosion, it needs to be addressed and clarified before we can examine the different types of weathering.Erosion can be a direct result of weathering and have the same impact on the environment. Atmospheric conditions (weather) can also be responsible for this occurrence. As a result, it is essential to understand how it differs from weathering to eliminate any confusion.The most significant difference between weathering and erosion rests on the location where the event takes place. In the case of weathering, the object gets weakened and broken down while it remains in the same position. In the case of erosion, the object is weakened and broken down by moving fragments or weathered parts of the object away from its original location. As we discuss the causes of weathering, the differences between the two processes will become much clearer.What Causes Weathering?There are a variety of ways in which the weathering breakdown process takes place. These various processes will determine the time, as well as the extent to which weathering occurs.For example, the time it takes for different objects to break down completely will depend on individual variables. This can include the object's characteristics, the amount of time it is exposed to the elements, and the types of weather variables it is exposed to.Weathering can broadly be divided into two categories:Mechanical (Physical) WeatheringChemical WeatheringWithin these two sections, different processes and atmospheric elements are working in their unique ways to weaken and break down objects on the surface. By examining how these different processes work within each of the two main categories, you will be able to get a much better understanding of how the various weathering processes work.1) Mechanical (Physical) WeatheringMechanical weather is the weakening and breakdown of objects like rocks, bricks, and concrete through a process called abrasion. (Abrasion is the process that use friction to break down an object through rubbing, scratching, and chaffing.) A good example to demonstrate this process is the weathering of a rock which is exposed to the elements 24 hours a day. In this case, more than one element is involved in the mechanical weathering process.Frost WeatheringDuring a rain shower, moisture is able to infiltrate small cracks within the rock. In regions where the temperature drops to below zero, the moisture within the rock freezes, which causes the cracks in the rock to expand.Continuous freezing and melting of the moisture within the rock force the small cracks to keep on expanding and contracting. This leads to the weakening of the rock's structure, which will cause it to break apart over time. Thermal weatheringRegions experiencing extreme temperatures of heat and cold, like deserts, are prone to another form of physical weathering.When a rock is exposed to extreme heat, the outer layer of the stone may expand at a faster rate than the inside. Similarly, during the cold nights, the rapid cooling down of the rock causes the outer layer to contract more quickly than the inside.In the short-term, this will cause flaking and erosion of the outer layer of the rock. In the long term, however, the constant stress on the rock may cause it to break apart completely.Other elements, including biological agents, are also responsible for mechanical weathering, but since we are focusing on weather-related weathering, we will disregard these additional factors for the purpose of this article.2) Chemical WeatheringUnlike mechanical weathering, where abrasion is the primary factor, chemical weathering takes place as a result of slow changes in the composition of an object, primarily as a result of interaction with water. For example, carbon dioxide within rainwater can cause a reaction within a rock to form carbonic acid, which dissolves some of the minerals inside that forms part of the structure. Carbonation And DissolutionAs previously mentioned, carbon dioxide in the rainwater can infiltrate a rock and combine to form a mild carbonic acid, which can dissolve some minerals within the rock.To find out more about the importance of carbon dioxide, its impact on the weather and climate change, read the in-depth article here.Changes in the atmosphere due to the excess release of fossil fuels and volcanic eruptions lead to the buildup of large volumes of gases such as sulfur dioxide and nitrogen oxide.These gases combine with water drops in the air to form sulfuric and similar acids. These highly toxic acids cause a much faster deterioration of rock, bricks, and concrete due to solution weathering.OxidationThis form of weathering occurs when water moisture interacts with various metals within an object, which results in an oxidation process (better known as rusting) which weakens the item to the point where corrosion causes it to break apart eventually. For example, rocks rich in iron also interact with water, which leads to oxidation, resulting in corrosion and the potential breakup of the rock over time. The reddish color that is so synonymous with rust is clearly visible in rock fragments that went through this process.HydrationPorous rocks and similar objects with microscopic openings and cracks allow water to infiltrate and saturate them, increasing the total volume of the object.A fully hydrated object causes stress on the already rigid structure of a rock or artifact. This can lead to a form of mechanical weathering where the additional stress can cause an object to fracture.This increase in volume is mainly due to water interacting with a substance within a rock to change into another substance with an increased volume. Examples include anhydrite turning into gypsum and hematite turning into limonite.Although classified as erosion, some forms of erosion are caused by weather elements and are the direct result of weathering. Therefore they are relevant and need to be included. After all, they are part of the overarching weathering process due to the weather.3) Wind ErosionOne of the weather elements responsible for some of the most extensive weathering and eroding the landscape is wind erosion.In short, wind erosion is the removal of loose or partly loosened soil and sand from one location to another. It can take place in areas where natural or human-made weathering of the landscape created loose and exposed particles on the surface.It is a very natural process that is forever changing the landscape in dry and sandy areas like deserts and semi-arid regions. What is more disconcerting is the removal of soil and sand that has been exposed due to human interference. Activities like deforestation, the removal of vegetation from coastal areas, and along riverbanks are now exposing large areas to wind potential wind erosion.This causes long-term damage to the environment as topsoil necessary for plants and crops to grow is carried away by the wind. The removal of soil from areas along riverbanks and coastal areas allows water to further erode and change entire landscapes. You may not realize just how important wind is and that it is one of the main driving forces of weather and responsible for reshaping entire landscapes. If you need any convincing, just read about gale force winds and the destructive power of wind in a tornado or cyclone.The Effects Of WeatheringYou see the effects of weathering all around you without even realizing it. When you look at a mountain with its foothills, you look at the effects of weathering. If you look at the stunning rock formations in the desert or at the coast, you are also viewing the effects of weathering.Although we can see the effects of weathering in broken or worn-down stones and rocks, as well as human-made objects like bricks and concrete in worn-down infrastructures and ruins, the best example of weathering is the sight of a huge mountain with its foothills.Transformation And Molding Of The Landscape The typical image of a mountain we see today is the result of millions of years of weathering. Tectonic plate activity or magma movement causes a piece of rock or magma to be pushed up high above the earth's crust.MountainsThe massive mountain that just formed is still just a piece of rock towering into the sky. It is immediately exposed to the element, however, causing all the different types of weathering we discussed in earlier sections to start "eating away" at it.As rocks are weakened and fragmented at the surface on top of the mountain, pieces started rolling down the sides while erosion breaks them down even further. At the bottom, they accumulate and are weathered and broken up even further.Over time, a combination of erosion and infiltration & breakdown by biological agents turns the small fragments of rock into the fertile soil/sediment that forms the green foothills we find today at the bottom of a mountain. This whole process can take millions of years or more to complete.Valleys and CanyonsWeathering can occur on relatively flat surfaces as well. Many of the valleys and canyons we see today are the result of weathering and erosion that slowly created their own path through the rock, leaving some spectacular landscapes behind.Not all surfaces are created equal. This is very evident as vast flat regions got exposed to weather elements long ago. Rocks that were more vulnerable to weathering than their neighbors got exposed fairly quickly (in geological terms).This may be due to the rock's porous structure or the fact that it contains metals/minerals that combine with rainwater to weaken its structure. These rocks weaken and weather away over time, which left indentations all over these flat regions with the help of wind erosion.When these areas received a fair amount of rain, especially on a very slight incline, the rainwater would have looked for the easiest runoff area possible. As the water followed the path of least resistance, the weathered indentations on the surface became an easy target.The water followed a path from one indentation to another as it started creating its own runoff pathway. Over time these paths became more established as the water began to erode the rock underneath it away.Today, we see the result of millions of years of the continuous process just described, slowly but persistently craving out the landscapes we are familiar with. It is an example of the power of weathering and erosion consistently and repeatedly applied over a million years.Old Infrastructure And RuinsThe same type of weathering that is responsible for the eroding and breakdown of stone, also affect the infrastructure of buildings.Bricks, concrete, and wood commonly used in the construction of buildings are also subject to both mechanical and chemical weathering. Human-made building blocks of solid infrastructures like brick and concrete are even more susceptible to weathering than rock. As a result, weathering takes place much faster on these objects than on stone. If not properly treated and maintained, bricks and concrete can start to show signs of weathering over a few decades and fragment and completely break down over a couple of centuries.You see the evidence of this accelerated form of weathering when you visit ghost towns in rural areas that were abandoned decades or centuries ago. You will quickly notice the various degrees of weathering, depending on the types of building material that were used.On the other hand, when you visit the ancient ruins build by civilizations that existed thousands of years ago, you will be surprised at how well some of these infrastructures stood the test of time, even in conditions conducive to weathering and erosion. Because these ancient civilizations used natural rock and stone to build their structures, some of which were huge and detailed, it was able to withstand the weathering and erosion processes much better than today's modern building materials.Just look at the pyramids of the ancient Mayans in Mexico and Central America, as well as the structures built by the Incas in Central America. Their well-preserved ruins are a testament to their resilience to extensive weathering and erosion over thousands of years.Weathering Effects On The Human BodyYou all would have heard an elderly person referred to as having a "weathered face." The same applies to people who are unfortunate enough to "living it rough" on the streets.Even the human body doesn't escape the weathering effects of the elements, specifically those people who are directly exposed to the elements throughout the day. And it is our bodies' skin that gets hit the hardest.Over time, continuous exposure to sun and dry air cause a variety of skin conditions. One of the most common effects of years of sun exposure is severely wrinkled & dry skin that occurs at different ages, depending on the individual and amount of time spent in the sun.As we all know, there are more dangerous consequences for sun exposure as well. Sunspots, cracked skin, and more severe conditions like solar keratosis and skin cancer are all the result of extensive exposure to the sun.Continuous exposure to weather elements affects other parts of the body as well, but then we start moving away from the weathering process, so that is not relevant to this article.ConclusionYou will now have a clear understanding of what exactly weathering is, how it is formed, and how the different types of weathering work together to weaken and break up an object.You will also understand why weathering and erosion are so closely related and often get confused with each other. Although they are not the same process, they often go hand-in-hand, and in many cases, the weather creates the ideal conditions for erosion to take place.I trust this post was able to answer any questions you might have regarding weathering and how it occurs.Never miss out again when another interesting and helpful article is released and stay updated, while also receiving helpful tips & information by simply clicking on this link .Until next time, keep your eye on the weather! Deterioration of rocks and minerals through exposure to the elements This article is about weathering of rocks and minerals. For weathering of polymers, see Polymer degradation and Weather testing of polymers. For the public health concept, see Weathering hypothesis. A natural arch produced by erosion of differentially weathered rock in Jebel Kharaz (Jordan) Part of a series onGeology Index Outline Category Glossary History (Timeline) Key components Minerals Rock (Igneous Sedimentary Metamorphic) Sediment Plate tectonics Strata Weathering Erosion Geologic time scale Laws, principles, theories Stratigraphic principles Principle of original horizontality Law of superposition Principle of lateral continuity Principle of cross-cutting relationships Principle of faunal succession Principle of inclusions and components Walther's law Topics Composition Geochemistry Mineralogy Sedimentology Petrology Structure of Earth Geophysics Landform structures Geomorphology Glaciology Structural Geology Volcanology Geologic history Geological history of Earth Research Branches of geology Geologist (List) Methods Geological survey Applications Engineering Mining Forensics Military Planetary geology Lists of geological features of the Solar System Geology of solar terrestrial planets By planet and body Mercury Venus Moon Mars Vesta Ceres Io Titan Triton Pluto Charon Geology portalvte Weathering is the deterioration of rocks, soils and minerals (as well as wood and artificial materials) through contact with water, atmospheric gases, sunlight, and biological organisms. It occurs in situ (on-site, with little or no movement), and so is distinct from erosion, which involves the transport of rocks and minerals by agents such as water, ice, snow, wind, waves and gravity. Weathering processes are either physical or chemical. The former involves the breakdown of rocks and soils through such mechanical effects as heat, water, ice and wind. The latter covers reactions to water, atmospheric gases and biologically produced chemicals with rocks and soils. Water is the principal agent behind both kinds,[1] though atmospheric oxygen and carbon dioxide and the activities of biological organisms are also important.[2] Biological chemical weathering is also called biological weathering.[3] The materials left after the rock breaks down combine with organic material to create soil. Many of Earth's landforms and landscapes are the result of weathering, erosion and redeposition. Weathering is a crucial part of the rock cycle; sedimentary rock, the product of weathered rock, covers 66% of the Earth's continents and much of the ocean floor.[4] Physical weathering, also called mechanical weathering or disaggregation, is the class of processes that causes the disintegration of rocks without chemical change. Physical weathering involves the breakdown of rocks into smaller fragments through processes such as expansion and contraction, mainly due to temperature changes.

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Weathering and Its Different Types The Wikibook Historical Geology has a page on the topic of: Mechanical weathering and erosion The Wikibook Historical Geology has a page on the topic of: Chemical weathering Look up weathering in Wiktionary, the free dictionary. Wikimedia Commons has media related to Weathering. Wikiversity has learning resources about Weathering Retrieved from "Second-largest asteroid of the main asteroid belt This article is about the asteroid. For the Roman goddess, see Vesta (mythology). For other uses, see Vesta (disambiguation). 4 VestaTrue color image of Vesta taken by Dawn. The massive Rheasilvia crater dominates Vesta's south pole.DiscoveryDiscovered byHeinrich Wilhelm Olbers Discovery date29 March 1807DesignationsMPC designation(4) VestaPronunciation/ˈvɛstə/[1]Named afterVestaMinor planet categoryMain belt (Vesta family)AdjectivesVestan Vestian[2]Symbol (historically astronomical, now astrological)Orbital characteristics[6]Epoch 13 September 2023(JD 2453300.5)Aphelion2.57 AU (384 million km)Perihelion2.15 AU (322 million km)Semi-major axis2.36 AU (353 million km)Eccentricity0.0894Orbital period (sidereal)3.63 yr (1325.86 d)Average orbital speed19.34 km/sMean anomaly169.4°Inclination7.1422° to ecliptic5.58° to invariable plane[7]Longitude of ascending node103.71°Time of perihelion26 December 2021[8]Argument of perihelion151.66°SatellitesNoneEarth MOID1.14 AU (171 million km)Proper orbital elements[9]Proper semi-major axis2.36151 AUProper eccentricity0.098758Proper inclination6.39234°Proper mean motion99.1888 deg / yrProper orbital period3.62944 yr(1325.654 d)Precession of perihelion36.8729 (2343 years) arcsec / yrPrecession of the ascending node−39.5979 (2182 years) arcsec / yrPhysical characteristicsDimensions572.6 km × 557.2 km × 446.4 km[10]Mean diameter525.4±0.2 km[10]Flattening0.2204Surface area(8.66±0.2)×105 km2[b][11]Volume7.4970×107 km3[10]Mass2.590271±0.000058)×1020 kg[12]Mean density3.456±0.035 g/cm3[10]Equatorial surface gravity0.22 m/s2 (0.022 g0)Equatorial escape velocity0.36 km/sSynodic rotation period0.3715 d[citation needed]Sidereal rotation period0.2226 d (5.342 h)[6][13]Equatorial rotation velocity93.1 m/s[c]Axial tilt29°North pole right ascension20h 32m[d]North pole declination48°[d]Geometric albedo0.423[15]Temperaturemin: 75 K (−198 °C)max: 250 K (−23 °C)[16]Spectral typeV[6][17]Apparent magnitude5.1[18] to 8.48Absolute magnitude (H)3.20[6][15]Angular diameter0.70″ to 0.22″ Vesta (minor-planet designation: 4 Vesta) is one of the largest objects in the asteroid belt, with a mean diameter of 525 kilometres (326 mi).[10] It was discovered by the German astronomer Heinrich Wilhelm Matthias Olbers on 29 March 1807[6] and is named after Vesta, the virgin goddess of home and hearth from Roman mythology.[19] Vesta is thought to be the second-largest asteroid, both by mass and by volume, after the dwarf planet Ceres.[20][21][22] Measurements give it a nominal volume only slightly larger than that of Pallas (about 5% greater), but it is 25% to 30% more massive. It constitutes an estimated 9% of the mass of the asteroid belt.[23] Vesta is the only known remaining rocky protoplanet of the kind that formed the terrestrial planets.[24] Numerous fragments of Vesta were ejected by collisions one and two billion years ago that left two enormous craters occupying much of Vesta's southern hemisphere.[25][26] Debris from these events has fallen to Earth as howardite–eucrite–diogenite (HED) meteorites, which have been a rich source of information about Vesta.[27][28][29] Vesta is the brightest asteroid visible from Earth. It is regularly as bright as magnitude 5.1,[18] at which times it is faintly visible to the naked eye. Its maximum distance from the Sun is slightly greater than the minimum distance of Ceres from the Sun,[e] although its orbit lies entirely within that of Ceres.[30] NASA's Dawn spacecraft entered orbit around Vesta on 16 July 2011 for a one-year exploration and left the orbit of Vesta on 5 September 2012[31] en route to its final destination, Ceres. Researchers continue to examine data collected by Dawn for additional insights into the formation and history of Vesta.[32][33] Vesta, Ceres, and the Moon with sizes shown to scale Heinrich Olbers discovered Pallas in 1802, the year after the discovery of Ceres. He proposed that the two objects were the remnants of a destroyed planet. He sent a letter with his proposal to the British astronomer William Herschel, suggesting that a search near the locations where the orbits of Ceres and Pallas intersected might reveal more fragments. These orbital intersections were located in the constellations of Cetus and Virgo.[34] Olbers commenced his search in 1802, and on 29 March 1807 he discovered Vesta in the constellation Virgo—a coincidence, because Ceres, Pallas, and Vesta are not fragments of a larger body. Because the asteroid Juno had been discovered in 1804, this made Vesta the fourth object to be identified in the region that is now known as the asteroid belt. The discovery was announced in a letter addressed to German astronomer Johann H. Schröter dated 31 March.[35] Because Olbers already had credit for discovering a planet (Pallas; at the time, the asteroids were considered to be planets), he gave the honor of naming his new discovery to German mathematician Carl Friedrich Gauss, whose orbital calculations had enabled astronomers to confirm the existence of Ceres, the first asteroid, and who had computed the orbit of the new planet in the remarkably short time of 10 hours.[36][37] Gauss decided on the Roman virgin goddess of home and hearth, Vesta.[38] Vesta was the fourth asteroid to be discovered, hence the number 4 in its formal designation. The name Vesta, or national variants thereof, is in international use with two exceptions: Greece and China. In Greek, the name adopted was the Hellenic equivalent of Vesta, Hestia (4 Εστία); in English, that name is used for 46 Hestia (Greeks use the name "Hestia" for both, with the minor-planet numbers used for disambiguation). In Chinese, Vesta is called the 'hearth-god(dess) star', 灶神星 Zàoshénxīng, naming the asteroid for Vesta's role, similar to the Chinese names of Uranus, Neptune, and Pluto.[f] Upon its discovery, Vesta was, like Ceres, Pallas, and Juno before it, classified as a planet and given a planetary symbol. The symbol represented the altar of Vesta with its sacred fire and was designed by Gauss.[39][40] In Gauss's conception, now obsolete, this was drawn . His form is in the pipeline for Unicode 17.0 as U+1F777 .[41][42][g] The asteroid symbols were gradually retired from astronomical use after 1852, but the symbols for the first four asteroids were resurrected for astrology in the 1970s. The abbreviated modern astrological variant of the Vesta symbol is (U+26B6 ⚶).[41][h] After the discovery of Vesta, no further objects were discovered for 38 years, and during this time the Solar System was thought to have eleven planets.[47] However, in 1845, new asteroids started being discovered at a rapid pace, and by 1851 there were fifteen, each with its own symbol, in addition to the eight major planets (Neptune had been discovered in 1846). It soon became clear that it would be impractical to continue inventing new planetary symbols indefinitely, and some of the existing ones proved difficult to draw quickly. That year, the problem was addressed by Benjamin Apthorp Gould, who suggested numbering asteroids in their order of discovery, and placing this number in a disk (circle) as the generic symbol of an asteroid. Thus, the fourth asteroid, Vesta, acquired the generic symbol ④. This was soon coupled with the name into an official number–name designation, ④ Vesta, as the number of minor planets increased. By 1858, the circle had been simplified to parentheses, (4) Vesta, which were easier to typeset. Other punctuation, such as 4) Vesta and 4, Vesta, was also briefly used, but had more or less completely died out by 1949.[48] SPHERE image is shown on the left, with a synthetic view derived from Dawn images shown on the right for comparison.[49] Photometric observations of Vesta were made at the Harvard College Observatory in 1880–1882 and at the Observatoire de Toulouse in 1909. These and other observations allowed the rotation rate of Vesta to be determined by the 1950s. However, the early estimates of the rotation rate came into question because the light curve included variations in both shape and albedo.[50] Early estimates of the diameter of Vesta ranged from 383 kilometres (238 mi) in 1825, to 444 km (276 mi). E.C. Pickering produced an estimated diameter of 513 ± 17 km (319 ± 11 mi) in 1879, which is close to the modern value for the mean diameter, but the subsequent estimates ranged from a low of 390 km (242 mi) up to a high of 602 km (374 mi) during the next century. The measured estimates were based on photometry. In 1989, speckle interferometry was used to measure a dimension that varied between 498 and 548 km (309 and 341 mi) during the rotational period.[51] In 1991, an occultation of the star SAO 93228 by Vesta was observed from multiple locations in the eastern United States and Canada. Based on observations from 14 different sites, the best fit to the data was an elliptical profile with dimensions of about 550 km × 462 km (342 mi × 287 mi).[52] Dawn confirmed this measurement.[i] These measurements will help determine the thermal history, size of the core, role of water in asteroid evolution and what meteorites found on Earth come from these bodies, with the ultimate goal of understanding the conditions and processes present at the solar system's earliest epoch and the role of water content and size in planetary evolution.[53] Vesta became the first asteroid to have its mass determined. Every 18 years, the asteroid 197 Arete approaches within 0.04 AU of Vesta. In 1966, based upon observations of Vesta's gravitational perturbations of Arete, Hans G. Hertz estimated the mass of Vesta at (1.20±0.08)×10−10 M☉ (solar masses).[54] More refined estimates followed, and in 2001 the perturbations of 17 Thetis were used to calculate the mass of Vesta to be (1.31±0.02)×10−10 M☉.[55] Dawn determined it to be 1.3029×10−10 M☉. Vesta orbits the Sun between Mars and Jupiter, within the asteroid belt, with a period of 3.6 Earth years,[6] specifically in the inner asteroid belt, interior to the Kirkwood gap at 2.50 AU. Its orbit is moderately inclined (i = 7.1°, compared to 7° for Mercury and 17° for Pluto) and moderately eccentric (e = 0.09, about the same as for Mars).[6] True orbital resonances between asteroids are considered unlikely. Because of their small masses relative to their large separations, such relationships should be very rare.[56] Nevertheless, Vesta is able to capture other asteroids into temporary 1:1 resonant orbital relationships (for periods up to 2 million years or more) and about forty such objects have been identified.[57] Decameter-sized objects detected in the vicinity of Vesta by Dawn may be such quasi-satellites rather than proper satellites.[57] Olbers Regio (dark area) defines the prime meridian in the IAU coordinate system. It is shown here in a Hubble shot of Vesta, because it is not visible in the more detailed Dawn images.Claudia crater (indicated by the arrow at the bottom of the closeup image at right) defines the prime meridian in the Dawn/NASA coordinate system. Vesta's rotation is relatively fast for an asteroid (5.342 h) and prograde, with the north pole pointing in the direction of right ascension 20 h 32 min, declination +48° (in the constellation Cygnus) with an uncertainty of about 10°. This gives an axial tilt of 29°.[58] Two longitudinal coordinate systems are used for Vesta, with prime meridians separated by 150°. The IAU established a coordinate system in 1997 based on Hubble photos, with the prime meridian running through the center of Olbers Regio, a dark feature 200 km across. When Dawn arrived at Vesta, mission scientists found that the location of the pole assumed by the IAU was off by 10°, so that the IAU coordinate system drifted across the surface of Vesta at 0.06° per year, and also that Olbers Regio was not discernible from up close, and so was not adequate to define the prime meridian with the precision they needed. They corrected the pole, but also established a new prime meridian 4° from the center of Claudia, a sharply defined crater 700 metres across, which they say results in a more logical set of mapping quadrangles.[59] All NASA publications, including images and maps of Vesta, use the Claudian meridian, which is unacceptable to the IAU. The IAU Working Group on Cartographic Coordinates and Rotational Elements recommended a coordinate system, correcting the pole but rotating the Claudian longitude by 150° to coincide with Olbers Regio.[60] It was accepted by the IAU, although it disrupts the maps prepared by the Dawn team, which had been positioned so they would not bisect any major surface features.[59][61] Relative sizes of the four largest asteroids. Vesta is second from left. This graph was using the legacy Graph extension, which is no longer supported. It needs to be converted to the new Chart extension.The mass of 4 Vesta (blue) compared to other large asteroids: 1 Ceres, 2 Pallas, 10 Hygiea, 704 Interamnia, 15 Eunomia and the Remainder of the Main Belt. The unit of mass is ×1018 kg. Other objects in the Solar System with well-defined masses within a factor of 2 of Vesta's mass are Varda, Gǃkúnǁʼhòmdímà, and Salacia (245, 136, and 492×1018 kg, respectively). No moons are in this range: the closest, Tethys (Saturn III) and Enceladus (Saturn II), are over twice and less than half of Vesta's mass. Vesta is the second most massive body in the asteroid belt, although it is only 28% as massive as Ceres, the most massive body.[62][23] Vesta is, however, the most massive body that formed in the asteroid belt, as Ceres is believed to have formed between Jupiter and Saturn. Vesta's density is lower than those of the four terrestrial planets but is higher than those of most asteroids, as well as all of the moons in the Solar System except Io. Vesta's surface area is about the same as the land area of Pakistan, Venezuela, Tanzania, or Nigeria; slightly under 900,000 km2 (350,000 sq mi; 90 million ha; 220 million acres). It has an only partially differentiated interior.[63] Vesta is only slightly larger (525.4±0.2 km[10]) than 2 Pallas (512±3 km) in mean diameter,[64] but is about 25% more massive. Vesta's shape is close to a gravitationally relaxed oblate spheroid,[58] but the large concavity and protrusion at the southern pole (see 'Surface features' below) combined with a mass less than 5×1020 kg precluded Vesta from automatically being considered a dwarf planet under International Astronomical Union (IAU) Resolution XXVI 5.[65] A 2012 analysis of Vesta's shape[66] and gravity field using data gathered by the Dawn spacecraft has shown that Vesta is currently not in hydrostatic equilibrium.[10][67] Temperatures on the surface have been estimated to lie between about −20 °C (253 K) with the Sun overhead, dropping to about −190 °C (83.1 K) at the winter pole. Typical daytime and nighttime temperatures are −60 °C (213 K) and −130 °C (143 K), respectively. This estimate is for 6 May 1996, very close to perihelion, although details vary somewhat with the seasons.[16] Further information: List of geological features on Vesta Before the arrival of the Dawn spacecraft, some Vestan surface features had already been resolved using the Hubble Space Telescope and ground-based telescopes (e.g., the Keck Observatory).[68] The arrival of Dawn in July 2011 revealed the complex surface of Vesta in detail.[69] Geologic map of Vesta (Mollweide projection).[70] The most ancient and heavily cratered regions are brown; areas modified by the Veneneia and Rheasilvia impacts are purple (the Saturnalia Fossae Formation, in the north)[71] and light cyan (the Divalia Fossae Formation, equatorial),[70] respectively; the Rheasilvia impact basin interior (in the south) is dark blue, and neighboring areas of Rheasilvia ejecta (including an area within Veneneia) are light purple-blue;[72][73] areas modified by more recent impacts or mass wasting are yellow/orange or green, respectively. Main articles: Rheasilvia and Veneneia Northern (left) and southern (right) hemispheres. The "Snowman" craters are at the top of the left image; Rheasilvia and Veneneia (green and blue) dominate the right. Parallel troughs are seen in both. Colors of the two hemispheres are not to scale,[j] and the equatorial region is not shown. South pole of Vesta, showing the extent of Rheasilvia crater. The most prominent of these surface features are two enormous impact basins, the 500-kilometre ({convert: unknown unit}) Rheasilvia, centered near the south pole; and the 400-kilometre-wide (249 mi) Veneneia. The Rheasilvia impact basin is younger and overlies the Veneneia.[74] The Dawn science team named the younger, more prominent crater Rheasilvia, after the mother of Romulus and Remus and a mythical vestal virgin.[75] Its width is 95% of the mean diameter of Vesta. The crater is about 19 km (12 mi) deep. A central peak rises 23 km (14 mi) above the lowest measured part of the crater floor and the highest measured part of the crater rim is 31 km (19 mi) above the crater floor low point. It is estimated that the impact responsible excavated about 1% of the volume of Vesta, and it is likely that the Vesta family and V-type asteroids are the products of this collision. If this is the case, then the fact that 10 km (6 mi) fragments have survived bombardment until the present indicates that the crater is at most only about 1 billion years old.[76] It would also be the site of origin of the HED meteorites. All the known V-type asteroids taken together account for only about 6% of the ejected volume, with the rest presumably either in small fragments, ejected by approaching the 3:1 Kirkwood gap, or perturbed away by the Yarkovsky effect or radiation pressure. Spectroscopic analyses of the Hubble images have shown that this crater has penetrated deep through several distinct layers of the crust, and possibly into the mantle, as indicated by spectral signatures of olivine.[58] Subsequent analysis of data from the Dawn mission provided much greater detail on Rheasilvia's structure and composition, confirming it as one of the largest impact structures in the solar system. The impact clearly modified the pre-existing very large, Veneneia structure, indicating Rheasilvia's younger age.[74] Rheasilvia's size makes Vesta's southern topography unique, creating a flattened southern hemisphere and contributing significantly to the asteroid's overall oblate shape.[69] Rheasilvia's ~22 km central peak stands as one of the tallest mountains identified in the Solar System.[74] Its base is wide at roughly 180 km and complex morphology distinguishes it from the simpler central peaks seen in smaller craters.[77] Numerical modeling indicates that such a large central structure within a ~505 km diameter basin requires formation on a differentiated body with significant gravity. Scaling laws for craters such a feature; instead, impact dynamics involving transient crater collapse and rebound of the underlying material (potentially upper mantle) are needed to explain its formation.[77] Hydrocode simulations suggest the impactor responsible was likely 60–70 km across, impacting at roughly 5.4 km/s.[78] Models of impact angle (around 30-45 degrees from vertical) better match the detailed morphology of the basin and its prominent peak.[77] Crater density measurements on Rheasilvia's relatively unmodified floor materials and surrounding ejecta deposits, calibrated using standard lunar chronology functions adapted for Vesta's location, place the impact event at approximately 1 billion years ago.[79][70] This age makes Rheasilvia a relatively young feature on a protoplanetary body formed early in Solar System history. The estimated excavation of ~1% of Vesta's volume[74] provides a direct link to the Vesta family of asteroids (Vestoids) and the HED meteorites. Since Vesta's spectral signature matches that of the Vestoids and HEDs, this strongly indicates they are fragments ejected from Vesta most likely during the Rheasilvia impact.[27][79] The Dawn mission's VIR instrument helped to confirm the basin's deep excavation and compositional diversity. VIR mapping revealed spectral variations across the basin consistent with the mixing of different crustal layers expected in the HED meteorites. Signatures matching eucrites (shallow crustal basalts) and diogenites (deeper crustal orthopyroxenites) were identified, which usually correlate with specific morphological features like crater walls or slump blocks.[80][27] The confirmed signature of olivine-rich material, which were first hinted at by Hubble observations is strongest on the flanks of the central peak and in specific patches along the basin rim and walls, suggesting it is not uniformly distributed but rather exposed in distinct outcrops.[81][82] As the dominant mineral expected in Vesta's mantle beneath the HED-like crust,[10] the presence of olivine indicates the Rheasilvia impact penetrated Vesta's entire crust (~20-40 km thick in the region) and excavated material from the upper mantle.[81] Furthermore, the global stresses resulting from this massive impact are considered the likely trigger for the formation of the large trough systems, like Divalia Fossae, that encircle Vesta's equatorial regions.[82][69] The crater Aelia Feralia Planitia, an old, degraded impact basin or crater complex near Vesta's equator (here given: 270 km (168 mi) across and predates Rheasilvia (green and bottom) Several old, degraded craters approach Rheasilvia and Veneneia in size, although none are quite so large. They include Feralia Planitia, shown at right, which is 270 km (168 mi) across.[83] More-recent, sharper craters range up to 158 km (98 mi) Varronilla and 196 km (122 mi) Postumia.[84] Dust fills up some craters, creating so-called dust ponds. They are a phenomenon where pockets of dust are seen in celestial bodies without a significant atmosphere. These are smooth deposits of dust accumulated in depressions on the surface of the body (like craters), contrasting from the Rocky terrain around them.[85] On the surface of Vesta, we have identified both type 1 (formed from impact melt) and type 2 (electrostatically made) dust ponds within 0°–30°N/S, that is, Equatorial region. 10 craters have been identified with such formations.[86] The "snowman craters" are a group of three adjacent craters in Vesta's northern hemisphere. Their official names, from largest to smallest (west to east), are Marcia, Calpurnia, and Minucia. Marcia is the youngest and cross-cuts Calpurnia. Minucia is the oldest.[70] "Snowman" craters by Dawn from 5,200 km (3,200 mi) in 2011Detailed image of the "Snowman" craters The majority of the equatorial region of Vesta is sculpted by a series of parallel troughs designated Divalia Fossae; its longest trough is 10–20 kilometres (6.2–12.4 mi) wide and 465 kilometres (289 mi) long. Despite the fact that Vesta is a one-seventh the size of the Moon, Divalia Fossae dwarfs the Grand Canyon. A second series, inclined to the equator, is found further north. This northern trough system is named Saturnalia Fossae, with its largest trough being roughly 40 km wide and over 370 km long. These troughs are thought to be large-scale graben resulting from the impacts that created Rheasilvia and Veneneia craters, respectively. They are some of the longest chasms in the Solar System, nearly as long as Ithaca Chasma on Tethys. The troughs may be graben that formed after another asteroid collided with Vesta, a process that can happen only in a body that is differentiated,[82] which Vesta may not fully be. Alternatively, it is proposed that the troughs may be radial sculptures created by secondary cratering from Rheasilvia.[87] A section of Divalia Fossae, with parallel troughs to the north and southA computer-generated view of a portion of Divalia Fossae Compositional information from the visible and infrared spectrometer (VIR), gamma-ray and neutron detector (GRaND), and framing camera (FC), all indicate that the majority of the surface composition of Vesta is consistent with the composition of the howardite, eucrite, and diogenite meteorites.[88][89][90] The Rheasilvia region is richest in diogenite, consistent with the Rheasilvia-forming impact excavating material from deeper within Vesta. The presence of olivine within the Rheasilvia region would also be consistent with excavation of mantle material. However, olivine has only been detected in localized regions of the northern hemisphere, not within Rheasilvia.[32] The origin of this olivine is currently unclear. Though olivine was expected by astronomers to have originated from Vesta's mantle prior to the arrival of the Dawn orbiter, the lack of olivine within the Rheasilvia and Veneneia impact basins complicates this view. Both impact basins excavated Vestian material down to 60–100 km, far deeper than the expected thickness of ~30–40 km for Vesta's crust. Vesta's crust may be far thicker than expected or the violent impact events that created Rheasilvia and Veneneia may have mixed material enough to obscure olivine from observations. Alternatively, Dawn observations of olivine could instead be due to delivery by olivine-rich impactors, unrelated to Vesta's internal structure.[91] Pitted terrain has been observed in four craters on Vesta: Marcia, Cornelia, Numisia and Licinia.[92] The formation of the pitted terrain is proposed to be degassing of impact-heated volatile-bearing material. Along with the pitted terrain, curvilinear gullies are found in Marcia and Cornelia craters. The curvilinear gullies end in lobate deposits, which are sometimes covered by pitted terrain, and are proposed to form by the transient flow of liquid water after buried deposits of ice were melted by the heat of the impacts.[71] Hydrated materials have also been detected, many of which are associated with areas of dark material.[93] Consequently, dark material is thought to be largely composed of carbonaceous chondrite, which was deposited on the surface by impacts. Carbonaceous chondrites are comparatively rich in mineralogically bound OH.[92] Cut-away schematic of Vestan core, mantle, and crust Eucrite meteorite A large collection of potential samples from Vesta is accessible to scientists, in the form of over 1200 HED meteorites (Vestan achondrites), giving insight into Vesta's geologic history and structure. NASA Infrared Telescope Facility (NASA IRTF) studies of asteroid (237442) 1999 TA10 suggest that it originated from deeper within Vesta than the HED meteorites.[94] Vesta is thought to consist of a metallic iron-nickel core, variously estimated to be 90 km[63] to 220 km[10] in diameter, an overlying rocky olivine mantle, with a surface crust of similar composition to HED meteorites. From the first appearance of calcium–aluminium-rich inclusions (the first solid matter in the Solar System, forming about 4.567 billion years ago), a likely time line is as follows:[95][96][97][98][99] Timeline of the evolution of Vesta 2–3 million years Accretion completed 4–5 million years Complete or almost complete melting due to radioactive decay of 26Al, leading to separation of the metal core 6–7 million years Progressive crystallization of a convecting molten mantle. Convection stopped when about 80% of the material had crystallized Extrusion of the remaining molten material to form the crust, either as basaltic lavas in progressive eruptions, or possibly forming a short-lived magma ocean. The deeper layers of the crust crystallize to form plutonic rocks, whereas older basalts are metamorphosed due to the pressure of newer surface layers. Slow cooling of the interior Vesta is the only known intact asteroid that has been resurfaced in this manner. Because of this, some scientists refer to Vesta as a protoplanet.[100] Composition of the Vestan crust (by depth)[101] A lithified regolith, the source of howardites and brecciated eucrites. Basaltic lava flows, a source of non-cumulate eucrites. Plutonic rocks consisting of pyroxene, pigeonite and plagioclase, the source of cumulate eucrites. Plutonic rocks rich in orthopyroxene with large grain sizes, the source of diogenites. On the basis of the sizes of V-type asteroids (thought to be pieces of Vesta's crust ejected during large impacts), and the depth of Rheasilvia crater (see below), the crust is thought to be roughly 10 kilometres (6 mi) thick.[102] Findings from the Dawn spacecraft have found evidence that the troughs that wrap around Vesta could be graben formed by impact-induced faulting (see Troughs section above), meaning that Vesta has more complex geology than other asteroids. The impacts that created the Rheasilvia and Veneneia craters occurred when Vesta was no longer warm and plastic enough to return to an equilibrium shape, distorting its once rounded shape and prohibiting it from being classified as a dwarf planet today.[citation needed] Vesta's surface is covered by regolith distinct from that found on the Moon or asteroids such as Itokawa. This is because space weathering acts differently. Vesta's surface shows no significant trace of nanophase iron because the impact speeds on Vesta are too low to make rock melting and vaporization an appreciable process. Instead, regolith evolution is dominated by brecciation and subsequent mixing of bright and dark components.[103] The dark component is probably due to the infall of carbonaceous material, whereas the bright component is the original Vesta basaltic soil.[104] Some small Solar System bodies are suspected to be fragments of Vesta caused by impacts. The Vestian asteroids and HED meteorites are examples. The V-type asteroid 1929 Kollaa has been determined to have a composition akin to cumulate eucrite meteorites, indicating its origin deep within Vesta's crust.[28] Vesta is currently one of only eight identified Solar System bodies of which we have physical samples, coming from a number of meteorites suspected to be Vestan fragments. It is estimated that 1 out of 16 meteorites originated from Vesta.[105] The other identified Solar System samples are from Earth itself, meteorites from Mars, meteorites from the Moon, and samples returned from the Moon, the comet Wild 2, and the asteroids 25143 Itokawa, 162173 Ryugu, and 101955 Bennu.[29][k] Animation of Dawn's trajectory from 27 September 2007 to 5 October 2018 Dawn · Earth · Mars · 4 Vesta · 1 Ceres First image of asteroids (Ceres and Vesta) taken from Mars. The image was made by the Curiosity rover on 20 April 2014. Animation of Dawn's trajectory around 4 Vesta from 15 July 2011 to 10 September 2012 Dawn · 4 Vesta In 1981, a proposal for an asteroid mission was submitted to the European Space Agency (ESA). Named the Asteroidal Gravity Optical and Radar Analysis (AGORA), this spacecraft was to launch some time in 1990–1994 and perform two flybys of large asteroids. The preferred target for this mission was Vesta. AGORA would reach the asteroid belt either by a gravitational slingshot trajectory past Mars or by means of a small ion engine. However, the proposal was refused by the ESA. A joint NASA–ESA asteroid mission was then drawn up for a Multiple Asteroid Orbiter with Solar Electric Propulsion (MAOSEP), with one of the mission profiles including an orbit of Vesta. NASA indicated they were not interested in an asteroid mission. Instead, the ESA set up a technological study of a spacecraft with an ion drive. Other missions to the asteroid belt were proposed in the 1980s by France, Germany, Italy and the United States, but none were approved.[106] Exploration of Vesta by fly-by and impacting penetrator was the second main target of the first plan of the multi-aimed Soviet Vesta mission, developed in cooperation with European countries for realisation in 1991–1994 but canceled due to the dissolution of the Soviet Union. Artist's conception of Dawn orbiting Vesta In the early 1990s, NASA initiated the Discovery Program, which was intended to be a series of low-cost scientific missions. In 1996, the program's study team recommended a mission to explore the asteroid belt using a spacecraft with an ion engine as a high priority. Funding for this program remained problematic for several years, but by 2004 the Dawn vehicle had passed its critical design review[107] and construction proceeded.[citation needed] It launched on 27 September 2007 as the first space mission to Vesta. On 3 May 2011, Dawn acquired its first targeting image 1.2 million kilometres from Vesta.[108] On 16 July 2011, NASA confirmed that it received telemetry from Dawn indicating that the spacecraft successfully entered Vesta's orbit.[109] It was scheduled to orbit Vesta for one year, until July 2012.[110] Dawn's arrival coincided with late summer in the southern hemisphere of Vesta, with the large crater at Vesta's south pole (Rheasilvia) in sunlight. Because a season on Vesta lasts eleven months, the northern hemisphere, including anticipated compression fractures opposite the crater, would become visible to Dawn's cameras before it left orbit.[111] Dawn left orbit around Vesta on 4 September 2012 11:26 p.m. PDT to travel to Ceres.[112] NASA/DLR released imagery and summary information from a survey orbit, two high-altitude orbits (60–70 m/pixel) and a low-altitude mapping orbit (20 m/pixel), including digital terrain models, videos and atlases.[113][114][115][116][117][118] Scientists also used Dawn to calculate Vesta's precise mass and gravity field. The subsequent determination of the J2 component yielded a core diameter estimate of about 220 km assuming a crustal density similar to that of the HED.[113] Dawn data can be accessed by the public at the UCLA website.[119] Albedo and spectral maps of Vesta, as determined from Hubble Space Telescope images from November 1994 Elevation map of Vesta, as determined from Hubble Space Telescope images of May 1996 Elevation diagram of Vesta (as determined from Hubble Space Telescope images of May 1996) viewed from the south-east, showing Rheasilvia crater at the south pole and Feralia Planitia near the equator Vesta seen by the Hubble Space Telescope in May 2007 The 2006 IAU draft proposal on the definition of a planet listed Vesta as a candidate.[120] Vesta is shown fourth from the left along the bottom row. Vesta comes into view as the Dawn spacecraft approaches and enters orbit: Vesta from 100,000 km(1 July 2011) Vesta from 41,000 km(9 July 2011) In orbit at 16,000 km(17 July 2011) In orbit from 10,500 km(18 July 2011) The northern hemisphere from 5,200 km(23 July 2011) In orbit from 5,200 km(24 July 2011) In orbit from 3,700 km(31 July 2011) Full rotation(1 August 2011) Composite greyscale image Cratered terrain with hills and ridges(6 August 2011) Densely cratered terrain near terminator(6 August 2011) Vestan craters in various states of degradation, with troughs at bottom(6 August 2011) Hill shaded central mound at the south pole of Vesta(2 February 2015) Detailed images retrieved during the high-altitude (60–70 m/pixel) and low-altitude (~20 m/pixel) mapping orbits are available on the Dawn Mission website of JPL/NASA.[121] Annotated image from Earth's surface in June 2007 with (4) Vesta Its size and unusually bright surface make Vesta the brightest asteroid, and it is occasionally visible to the naked eye from dark skies (without light pollution). In May and June 2007, Vesta reached a peak magnitude of +5.4, the brightest since 1989.[122] At that time, opposition and perihelion were only a few weeks apart.[123] It was brighter still at its 22 June 2018 opposition, reaching a magnitude of +5.3.[124] Less favorable oppositions during late autumn 2008 in the Northern Hemisphere still had Vesta at a magnitude from +6.5 to +7.3.[125] Even when in conjunction with the Sun, Vesta will have a magnitude around +8.5; thus from a pollution-free sky it can be observed with binoculars even at elongations much smaller than near opposition.[125] In 2010, Vesta reached opposition in the constellation of Leo on the night of 17–18 February, at about magnitude 6.1,[126] a brightness that makes it visible in binocular range but generally not for the naked eye. Under perfect dark sky conditions where all light pollution is absent it might be visible to an experienced observer without the use of a telescope or binoculars. Vesta came to opposition again on 5 August 2011, in the constellation of Capricornus at about magnitude 5.6.[126][127] Vesta was at opposition again on 9 December 2012.[128] According to Sky and Telescope magazine, this year Vesta came within about 6 degrees of 1 Ceres during the winter of 2012 and spring 2013.[129] Vesta orbits the Sun in 3.63 years and Ceres in 4.6 years, so every 17.4 years Vesta overtakes Ceres (the previous overtaking was in April 1996).[129] On 1 December 2012, Vesta had a magnitude of 6.6, but it had decreased to 8.4 by 1 May 2013.[129] Conjunction of Ceres and Vesta near the star Gamma Virginis on 5 July 2014 in the constellation of Virgo. Ceres and Vesta came within one degree of each other in the night sky in July 2014.[129] 3103 Eger 3551 Verenia 3908 Nyx 4055 Magellan Asteroids in fiction Diogenite Eucrite List of former planets Howardite Vesta family (vestoids) List of tallest mountains in the Solar System ^ Marc Rayman of the JPL Dawn team used "Vestian" (analogous to the Greek cognate Hestian) a few times in 2010 and early 2011 in his Dawn Journal, and the Planetary Society continued to use that form for a few more years.[2] The word had been used elsewhere, e.g. in Tsiolkovsky (1960) The call of the cosmos. However, otherwise the shorter form "Vestan" has been used by JPL.[3] Most modern print sources also use "Vestan".[4][5] Note that the related word "Vestalian" refers to people or things associated with Vesta, such as the vestal virgins, not Vesta herself. ^ Calculated using the known dimensions assuming an ellipsoid. ^ Calculated using (1) the known rotation period (5.342 h)[6] and (2) the equatorial radius Req (285 km)[10] of the best-fit biaxial ellipsoid to asteroid 4 Vesta. ^ a b Refers to the "Claudia" coordinate system currently used by the Dawn mission. It has been adopted by NASA, and it differs by 150 degrees from the "IAU-2000" system. The IAU accepted the "Claudia" system in 2013 with some modifications.[14] The Dawn system has a rotation of 150 degrees with respect to the one adopted by the IAU (the so-called "IAU-2000" frame). ^ On 10 February 2009, during Ceres perihelion, Ceres was closer to the Sun than Vesta, because Vesta has an aphelion distance greater than Ceres's perihelion distance. (10 February 2009: Vesta 2.56 AU; Ceres 2.54 AU) ^ 灶神星 also is the Chinese name for Hestia in that language.[citation needed] ^ Gauss's drawing of the symbol. ^ Other forms of the symbol have been proposed; see Bala (2018)[43][44] ^ A simplification of the latter from c. 1930, ,[45] never caught on. ^ This symbol can be seen in the top of the most elaborate of the earlier forms, . It dates from 1973, at the beginning of astrological interest in asteroids.[46] ^ The data returned will include, for both asteroids, full surface imagery, full surface spectrometric mapping, elemental abundances, topographic profiles, gravity fields, and mapping of remnant magnetism, if any.[53] ^ That is, blue in the north does not mean the same thing as blue in the south. ^ Note that 6 Hebe may be the parent body for H chondrites, one of the most common meteorite types. ^ "Vesta". Dictionary.com Unabridged (Online). n.d. ^ "Search Results". Planetary Society. Archived from the original on 27 July 2020. Retrieved 31 August 2012. ^ "Search – Dawn Mission". JPL. 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The Dawn Mission to Minor Planets 4 Vesta and 1 Ceres, Christopher T. Russell and Carol A. Raymond (Editors), Springer (2011), ISBN 978-1-4614-4903-4 Keil, K.; Geological History of Asteroid 4 Vesta: The Smallest Terrestrial Planet in Asteroids III, William Bottke, Alberto Cellino, Paolo Paolicchi, and Richard P. Binzel, (Editors), University of Arizona Press (2002), ISBN 0-8165-2281-2 Wikimedia Commons has media related to Vesta (asteroid). This video explores Vesta's landscape, history and future Interactive 3D gravity simulation of the Dawn spacecraft in orbit around Vesta Archived 11 June 2020 at the Wayback Machine Vesta Trek – An integrated map browser of datasets and maps for 4 Vesta JPL Ephemeris Views of the Solar System: Vesta Encyclopædia Britannica, Vesta – full article HubbleSite: short movie composed from Hubble Space Telescope images from November 1994. 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