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What is the relationship between mechanical weathering and chemical weathering

Revised 8 / 06 (Monroe 6th ed.) Weathering of Rock at the Surface of the Earth (Ch. 6) Including... Introduction General Review: a regional view Earth has 2 levels Below and above sea level Earth has 2 types of rock Basalt and granite Earth has 2 processes Construction and Destruction Over the course of geologic time these 2 are in balance Tectonics: the study of earth processes which result in the creation and deformation of magma and rock This builds the earth as we know it It's what we've studied up to this point The destructional processes are next Weathering Erosion Transportation These are the processes that tear down the mountains and save us all from nose bleeds This stuff can be mighty impressive Carve valleys Rivers and glaciers Basically erode the land and transport the debris to the beach But first the earth has to break it up because the mountains are too big to move in one piece Strickler's 3rd Law of GeoFantasy Surface conditions directly affect rock exposed at and near the surface Several factors contribute to surface weathering Climate Water content: dry --> moist --> wet --> saturated Temperature: cold vs. temperate vs. hot And all possible combinations Rock type Granite vs. limestone tombstones Limestone in humid vs. arid climates Pollution level A new twist compliments of human activities EXAMPLE: Egyptian Obelisk Soil Development and Loss Surface weathering also results in soil development (Monroe: fig. 6-14 thru 18, pg. 183 thru 186) Soils develop very slowly Can be considered "Our most valuable mineral resource" Without plain dirt, life as we know it... Soils reflect the rock material from which they are derived Different parent materials clearly result in different types of soils We won't spend a bunch of time on soils It's good stuff, but a class unto itself It's being lost at an alarming rate (Monroe: fig. 6-22, pg. 189) Many books dwell on how we are building on agricultural lands We can always tear them down Possibly more important is loss through increased erosion The result of stupidity, ignorance, and/or greed Permanent loss At least as far as our time scale is concerned Several ways to damage/destroy earth's soils Overgrazing - "desertification" Sub-Sahara Africa Overuse - "saltification" Lower Colorado River area Central Valley, California Over cutting - "rapenpillagization" Pacific NW logging practices Improper farming methods - blowitawayton" Midwest: 10' to 20' lost since mid-1800's in some areas Or more, locally Change from strip to contour plowing helped (Monroe: fig. 6-23, pg. 190) But still lots being lost "Every time the surface is disturbed..." Think about the 4-wheel drive ads on TV Glorifying off-road "fun and excitement" 4X4's for everyone!!! DIGRESS TO: C&G Pass and KGO EVERY cloud of dust is more topsoil being lost How fun is starvation We're in trouble And often focus on the wrong target The scars left by early day loggers and miners are truly insignificant when viewed against the excess of modern practices Much more on this when we get to erosion Weathering: an overview Top several meters of earth's crust Actual depth highly variable Fracturing due to unloading can extend much deeper (see below) The surface exposes most rocks to a different physio-chemical environment from where they formed Similar in concept to the metamorphic process A fundamental change in mineralogy due to changing environmental conditions It is possible to view surface weathering as just another type of metamorphism In this case resulting from the absence of heat and pressure And you end up with dirt instead of rock Three basic types of weathering Water is a major player in all three Water is called "the hidden devil in the ground" Physical/Mechanical Physical break-up of rocks Results in smaller pieces with the same chemical composition Chemical Decomposition and/or dissolution by chemical activity Results in smaller pieces with different chemical composition Biological activity Not really a process of it's own Can lead to both mechanical and chemical weathering Very few areas where it's all one kind or another However, there are many areas where one type will predominate (see below) Mechanical Weathering Also called physical weathering Smaller pieces / same stuff Two main types Fracturing and Abrasion Like the difference between a hammer and sandpaper Results in clastic sediments of all sizes Smaller than sand to huge blocks of rock Generally results in angular fragments and surfaces DIGRESS TO: angular, sub-rounded, and rounded Usually joint controlled But how do the joints get there? This is also a surface effect - rock at depth is real solid Allow entry of fluids and roots Lots of situations can lead to mechanical weathering In general terms, anything which disturbs the surface and moves material will lead to some mechanical weathering Rocks in a river Obviously, the energy of the river directly affects what is being moved DIGRESS TO: bed load vs. suspended load Rivers in flood stage have greater energy Can move larger pieces with greater force Therefore the potential for mechanical weathering is greater Moving sand and silt acts like sandpaper on the larger rocks in the river bed Also on each other Rocks hitting other rocks can break Making smaller pieces which can then become part of the suspended load Rock falls Usually break up when they hit bottom Ice - the big one Water has highly unusual properties REVIEW: water and magic Stress the density anomaly Water expands 9% when it freezes If it freezes in a confined space it can exert a tremendous outward force against walls Up to 4.3 million pounds/ft2 This should be enough to break just about anything! Water seeps into cracks in rocks Freezes from top down Seals off the last remaining area where expansion could take place DIGRESS TO: imagine if it froze from bottom up No cracking at all How would this affect the weathering process in the higher mountains? Widens cracks and pries rocks apart Called frost wedging (Monroe: fig. 6-3, pg. 172) Doesn't happen everywhere Likes cold areas with large daily temperature fluctuations Most effective when daily/weekly temperature range spans 32 deg. F Process slows when temperature never climbs above freezing Or never drops below freezing Salt Crystal Growth Most waters contain dissolved "salts" Lots of different materials, not just NaCl Water in soil or rocks starts to evaporate Increases the concentration of the dissolved minerals Leads to crystallization Can increase pressure and break-up rock or other materials EXAMPLE: Fence posts in Bonneville Salt Flats Generally most effective in arid regions Probably due to less water More frequent fluctuations above and below the saturation threshold Surface Unloading Most rocks form at depth where the pressure is greater than near the surface As the rock is tectonically moved upward, the decrease in pressure causes the rock to expand Leading to fractures and joints Exfoliation (Monroe: fig. 6-4/5, pg. 173/174) Most common in granitic rocks And others with a uniform, homogenous texture Looks like an onion skin Peels off rock layers At right angles to the direction of pressure release Can expand out into valley walls DIGRESS TO: Zimbabwe - ancient city Rock bursts Potential in new mine workings Deadly! Temperature changes Used to be thought capable of causing exfoliation due to diurnal temperature fluctuations Needs some moisture to set it off Alters and swells "susceptible minerals" Probably the mafics (WHY?) Basically a physical weathering process with a chemical catalyst Extremely high temperatures can also lead to fracturing Forest fires, nuclear bombs, Texas chili farts Chemical Weathering Over the course of geologic time everything gets dissolved See Strickler's 3rd and 4th Laws of GeoFantasy Occurs in all environments Most effective in hot and humid areas High temperatures and lots of water Abundant organics to make acids (see below) Minerals chemically react when exposed to water and heat Results in smaller pieces AND different stuff Makes rounded fragments and surfaces Water need to be able to touch the minerals Surface area VERY important! (Monroe: fig. 6-10, pg. 180) EXPLAIN FULLY High temperatures act as a catalyst Solution Dissolving of rocks by weak acids over a long period of time Stronger acids obviously dissolve rocks faster Don't usually occur in nature Organic acids Generally weak but very common in nature Carbonic acid most common H2O + CO2 --> H2CO3 CO2 is produced by the decay of organic material Combines with groundwater to make carbonic acid And directly from the atmosphere Combines with rain water ALL RAIN WATER is actually acid rain!!! Carbonic acid may be weak but it is real hard on calcium carbonate Limestone, dolomite, marble CaCO3 + H2CO3 --> Ca+2 + 2HCO3-1 Ions are removed by percolating solutions Can completely dissolve large amounts of limestone Results in lots of amazing topography Karst topography DIGRESS TO: sink holes, etc. Stronger acids can be produced locally Sulfuric acid (H2O + SO2 --> H2SO4) Groundwater in contact with sulfide minerals EXAMPLE: Tri-State mining area, Yukon well water, TAB Acid Spring Oxidation Transfer of electrons and the addition of oxygen Your basic rust (Monroe: fig. 6-8, pg. 179) Occurs to any and all iron bearing minerals Common reaction: 4FeO + O2 --> 2Fe2O3 (limonite) The oxygen comes directly from the atmosphere or from carbonic acid Commonly associated with sulfide mineral deposits Gossan Hydrolysis Transfer of electrons and the addition of hydrogen Commonly attacks feldspar minerals EXAMPLE: feldspar (orthoclase) + hydrogen (from carbonic acid) + water --> Kaolinite (clay) + silicic acid + potassium ions 2KAlSi3O8 + 2H+ + 9H2O --> H4Al2Si2O9 + 4H4SiO4 + 2K+ Hydrolysis makes clay (end up as shale) Clays - very small with 1 perfect cleavage (like the micas) Which clay is formed depends partly on the climate Humid: Kaolinite (used in soft ice cream) Arid: Montmorillonite - a water-poor clay Works well as a soil additive (swells and holds water) Also works great as kitty litter Hydrolysis also liberates ions to be used by plants Such as potassium as illustrated above Biological Weathering Weathering resulting from the action of organic materials Not really a process of it's own Can lead to both mechanical and chemical weathering Many possibilities Lichen, fungus, mold, etc. (Monroe: fig. 6-6a, pg. 174) Secrete acids which "etch" the rock Make subtle irregularities The plant can use these as anchors Plant roots Can grow into cracks - force them apart (Monroe: fig. 6-6b, pg. 174) Breaks rock - a mechanical process Increases surface area - leads to increased chemical attack Organic acids These can chemically weather the minerals Organic debris Falls and decomposes Releases carbon which can combine with water and the atmosphere to make acids Inter-relationships between weathering types It's like a cycle (remember the hydrologic cycle? Same idea) Biologic / physical (EX: tree roots in cracks) Biologic / chemical (EX: root acids) Chemical / physical (EX: decomposed granite) Physical / chemical (EX: Fracture and abrasion lead to increased surface area) Abrasion and "rock flour" Chemical / Biological (EX: leads to soil formation) And back to biologic weathering Core stones in granitic rocks (Monroe: fig. 6-1a, pg. 170) (Monroe: fig. 6-12, pg. 181) Relative Rates of Weathering Rates vary depending on minerals and rocks REVIEW: several factors contribute to surface weathering Climate Dry --> moist --> wet --> saturated Cold vs. temperate vs. hot Rock type Granite vs. limestone Limestone in humid vs. arid climates Pollution level Differential weathering (Monroe: fig. 6-2, pg. 171) Rocks/minerals which weather rapidly, erode rapidly Weathering rates directly affects topography we see DIGRESS TO: why is Grants Pass in a valley? Many common minerals weather quickly Related to the order of crystallization Bowen's Reaction Series Mafics weather quicker, felsics weather slower Sandstone - quartz is all that's left after repeated cycles of weathering GeoMan's Home Page | RCC Index | High School Geology Index You are GeoManiac number since April 1, 1997

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