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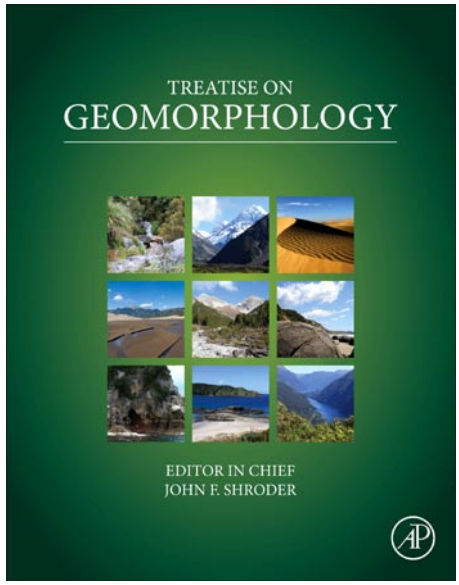

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4.17 Weathering and Sediment Genesis

GA Pope, Montclair State University, Montclair, NJ, USA

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Glossary

Arenization A process in granitic rock (but possibly also relevant to any coarse crystalline rock) by which chemical decomposition results in saprolite and the generation of coarse sand or gravel-sized fragments.

Bioturbation A process in soil and sediment by which plants or animals turn and displace material, thereby mixing the soil or sediment in a vertical sense.

Bog iron Iron deposit in wetlands formed of precipitated iron ions derived from weathering of other material.

Calcrete or caliche A pedogenic (soil formed) and indurated deposit of calcium carbonate, derived from the precipitation of calcium ions, usually found in arid and semiarid environments.

Case hardening Induration of the outer shell of rock by means of cementation by secondary minerals derived from weathering.

Chelation Chemical weathering process by which complex organic molecules (some proteins and amino acids, for instance) selectively extract metal ions from minerals, weakening the mineral.

Chemical weathering (chemical alteration) Breakup of rocks and minerals by way of chemical agents, removing material by molecules into solution; caused by any of several chemically reacting agents.

Clastic Term referring to particles of rock, of any size.

Clay 1) One of the phyllosilicate (layered) minerals usually formed from weathering of primary minerals or precipitated from solutes after weathering; 2) A class of particle, in the grain size scale, of any mineralogy, defined as being less than 4 μm in diameter.

Comminution Mechanical crushing and abrasion of sediments in transport.

Cosmogenic isotope dating Surface exposure dating technique that uses accumulation of unique and rare isotopes (such as Be^{10} or He^{3}), generated through interaction with high-energy cosmic rays.

Diagenesis Chemical or physical alteration to a sediment following deposition, leading to compaction and lithification. Usually excludes surface weathering, though transitional gradation to groundwater diagenesis is ill defined.

Disaggregation *In situ* breakup of rock particles to form smaller particles, distinct from chemical alteration but may be aided by chemical processes.

Fissuresols Fine grained sediments, weathering or aeolian in origin, accumulating in rock fractures.

Fragmentation Creation of rock pieces, influenced existing fractures or rock weaknesses, largely mechanical processes though aided by chemical processes. Predecessor to disaggregation.

Hydration Chemical weathering process by which a hydroxide ion is incorporated into the crystal structure, weakening the lattice. Noted in mica and clay minerals.

Laterite A residual weathering product concentrated in aluminum and iron oxides and depleted of silica and most other elements, often indurated.

Loess Windblown sediment of mostly silt-sized particles.

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Luminescence dating Surface exposure dating technique that measures accumulated radiation in minerals following most recent exposure to sunlight or intense heat.
Maturity In sediments, the composition and grain morphology relevant to the age and duration of transport; more mature sediments are of one mineralogy (usually quartz), and with well-rounded and well-sorted grains.
Mechanical weathering Breakup of rocks and minerals without chemical alteration, created by physical forces of pressure, strain, or shear, caused any of several agents: crystal growth (including ice), expansion or contraction due to changes in temperature, relaxation due to removal of pressure (unloading), and pressure from plant roots.
Neoformed minerals see *secondary minerals*.
Oxidation Chemical weathering process by which oxygen molecule is incorporated into the crystal structure, weakening the lattice. Oxidation of iron imparts reddish to yellowish colors in rocks, minerals, and soils.
Periglacial Describes processes related to nonglacial ice, and regions dominated by these processes (some of which may have been previously glaciated, others never glaciated but still cold).
Proglacial Area immediately down-gradient from or in front of a glacier.
Regolith Encompassing term for unconsolidated material at the Earth's surface, including soil, sediments, and weathered rock.
Sand In the grain size scale, a class of particles ranging from 62.5 μm to 2 mm in diameter.
Saprolite Any weathered bedrock that remains *in situ*.
Scree Rock fragments, usually angular, caused by weathering, that accumulate on slopes. Sometimes erroneously referred to as 'talus', which is more properly the landform of a scree deposit.
Secondary minerals Minerals created from the solute products of weathering or altered *in situ* by weathering (as opposed to primary minerals which derive from magma). Sometimes referred to as neoformed minerals.
Sediment Particles or dissolved material, derived from rock and mineral weathering, that is carried by surface processes of water, ice, wind, or gravity.
Silt In the grain size scale, a class of particles ranging from 4 μm to 62.5 μm in diameter.
Structure In rock, the inherent physical properties of the rock, including jointing, faulting, folding, bedding, or foliation.

Abstract

The genesis of detrital sediments could not take place without weathering. Both chemical and mechanical weathering processes work toward the fragmentation, disaggregation, and chemical alteration of rocks to form clastic particles (clay to boulder size) and solutes. Clastic particles are entrained into the sediment system by various geomorphic processes. Solutes indurate soils and near surface sediments as well as cementing buried sediments. The weathering genesis of particles and weathering of sediments becomes relevant to concerns within geomorphology and sedimentology, including the recognition of fine-grained particles derived from weathering, and the implications of sediment weathering on environmental factors and dating methods.

4.17.1 Weathering, Sediments, and the Rock Cycle

Sediments are a significant concern in the science of geomorphology. The overwhelming majority of these sediments are generated by weathering processes: no weathering, no sediment, nothing to transport or deposit. Weathering is a critical node in the 'rock cycle' published in many forms in innumerable introductory textbooks (Figure 1), most of which quickly mention the process that can attack any rock to start the sedimentary rock segment. Not usually included in this diagram is the feedback of direct weathering products (included in Figure 1), the near-surface, neoformed, *in situ* minerals that in many cases cement or otherwise solidify soil and regolith, prior to entering the sediment system. These byproducts, too, can weather, an additional step on the way to the sediment system. Weathering is equal in importance to magma production in the rock cycle process; both are responsible for recycling of earth materials and genesis of new materials.

White et al. (1992) also in an introductory textbook, provided a more directly focused diagram of the weathering system (Figure 2), the specific segment within the rock cycle. In this cascading system, rock breakdown produces rock and mineral fragments and mobile and residual chemical products, all of which may be temporarily stored in the regolith, recycled, or leave the local system to enter the detrital sediment and dissolved solute budget. A feedback loop is suggested in the weathering of end product and new material created by the weathering process. The diagram was intended as a simplified representation, in reality probably more interaction and parallel development of chemical and mechanical weathering agents occurs at all stages. Chemical weathering helps the mechanical fragmentation and disaggregation process, whereas mechanical forces continue to work during the chemical alteration process.

4.17.2 Processes: Disintegration and Chemical Alteration

The processes by which rock is broken down in the sedimentary system involve both disaggregation and chemical alteration. Details of these processes are covered by other chapters in this

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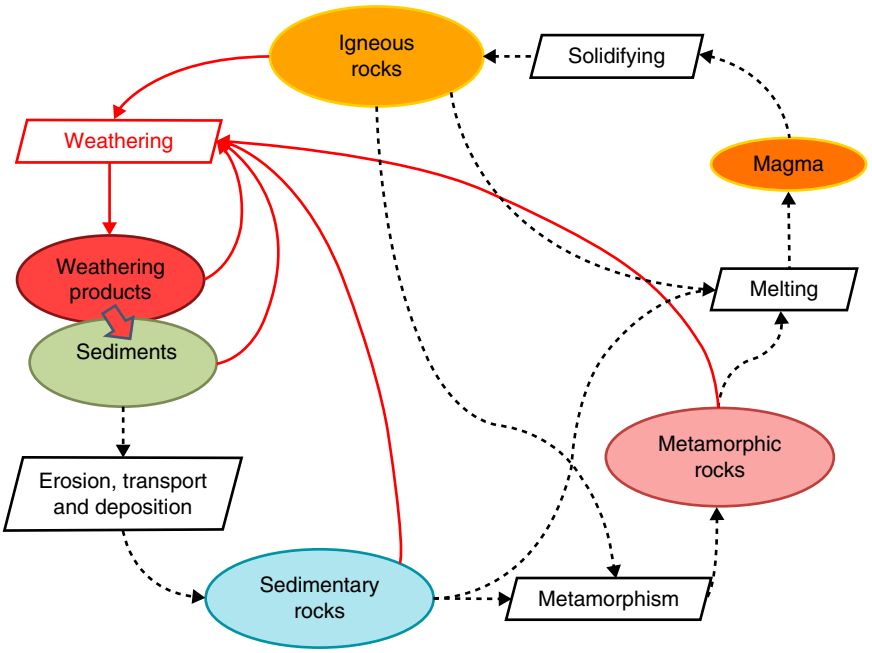

Figure 1 The rock cycle.

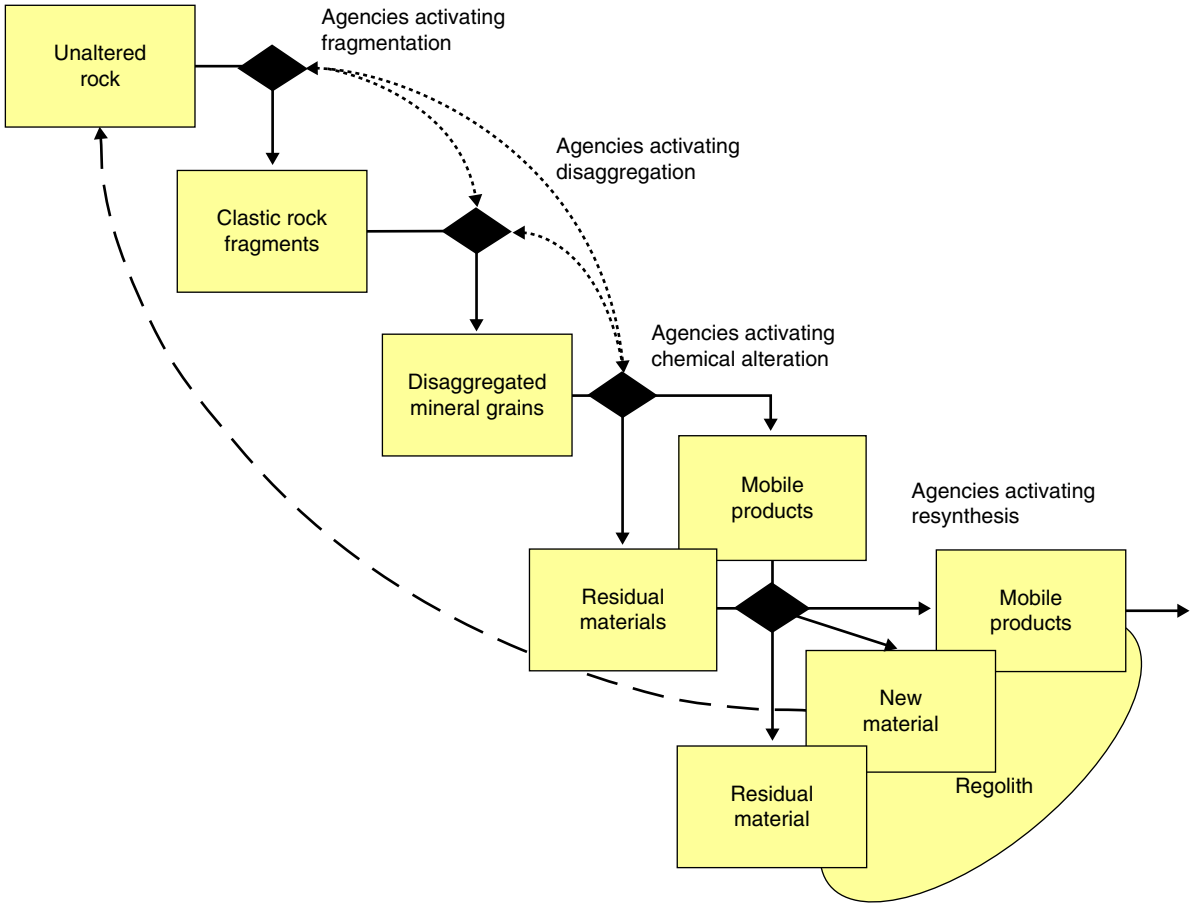

Figure 2 Weathering system, generating particles and chemical solutes. Reproduced from White, I.D., Mottershead, D.N., Harris, S.J., 1992. Environmental Systems: An Introductory Text, Second edn. Chapman and Hall.

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book, respective to different geomorphologies, but can be briefly outlined here. Disaggregation is the *in situ* breakup of rock particles to form smaller particles. Fragmentation begins this process by creating rock pieces, largely controlled by preexisting fractures or other rock weaknesses (such as bedding or foliation). Such fragments range in size from millimeters to many meters in diameter. Disaggregation continues with the release of individual crystalline grains, crystal fragments, clusters of crystals, or, in the case of existing sedimentary rocks, individual detrital particles (e.g., sand, silt, or clay).

Mechanical weathering processes are important in the fragmentation and disaggregation. Ice, salt, and neoformed minerals (such as iron and quartz) are similar in their ability to grow crystals within confined pore spaces or fractures, exerting enough pressure to cause brittle fracture. Plant roots likewise are able to expand within fractures and microfractures. Anisotropic response to heating and cooling (in rocks or individual crystals) causes thermal shock over extreme events or rock fabric fatigue over long periods (*see* Chapters 4.15 and 4.12). Drying and wetting cycles can be particularly relevant to shrink–swell clay minerals such as vermiculite and smectite, a mechanism for the mechanical release of clay-size particles. Finally, dilation or pressure unloading follows the release of overburden, after rapid erosion or melting of large glacial mass. These mechanical processes do not operate devoid of chemical weathering; chemical weathering helps to open existing weaknesses to further attack, including mechanical weathering. The White et al. (1992) weathering system (**Figure 2**) would be most accurate to consider chemical weathering happening in parallel to mechanical weathering, even at the onset of exposure of unaltered rock.

Chemical alteration includes any of the chemical weathering processes. Dissolution (hydrolysis) would be most important for the silicate minerals, whereas solution would be most relevant specifically to rocks containing quartz and calcite. Other chemical weathering processes include oxidation, hydration (addition of oxygen or hydroxide molecules, respectively, to the mineral matrix), and chelation (selective removal of metallic ions by organic agents). Some of these processes target specific minerals. Biotite, for instance, is vulnerable to oxidation and chelation. Loss of the specific minerals would in turn weaken the rock matrix, a factor in the arenization of some granitic rocks. Not only the loss of entire minerals, but also the ionic loss from chemical weathering cause intramineral voids, ultimately decreasing the unit weight (bulk density) of the rock (McNally, 1992) and leading to more rapid disintegration as well as collapse of weathering profiles.

4.17.3 Factors of Weathering Relevant to Sediment Production

Prothero and Schwab (1996) outlined several factors controlling the processes of sediment generation by weathering. These factors are similar to those promoted by Johnsson (1993), Hill and Rosenbaum (1998), and Pope et al. (1995).

4.17.3.1 Parent Material

The parent material rock has a composition that encompasses the mineralogy, texture, and rock structure of the host rock. Mineralogy renders an inherent weathering susceptibility, owing to the elemental content and crystal structure. This familiar relationship introduced by Goldich (1938) is sometimes overwhelmed by environmental factors (Wasklewicz, 1994). Rocks composed of different mineralogies (for instance, granite) will undergo differential weathering, the more weatherable minerals are the first to fail, but this also compromises the integrity of the entire rock, in that more resistant mineral grains (such as quartz) can more easily enter the sediment train.

Structure and texture are related in their control of access to weathering agents and importance to the strength of the rock fabric. In general, fine-grained rocks (such as volcanic, mudstone, and slate) are more susceptible to chemical weathering due to their increased surface area per unit volume (sometimes referred to as the wetted surface area). Rock structure includes fissuring and jointing in the rock, foliation (in metamorphic rocks), and bedding (in sedimentary rocks). In general, increased joint density and finer foliation or bedding promote increased weathering. Bedding, foliation, and jointing interrupt the rock fabric and provide conduits for moisture (aiding chemical weathering and providing access for mechanical weathering such as salt crystallization or ice). At large scales, the spatial distribution of resistant rock landforms is determined by joint density (Young et al., 2009; Twidale and Romani, 2005; Campbell, 1997).

4.17.3.2 Climate

Climate influences the amount and seasonality of precipitation, the mean and variation in temperature, and in turn the type of ecosystem with associated biota. All of these elements are important to weathering, though the relationships are not always as simple as presumed (*see* Chapters 4.3, 4.14, 13.11, 4.15, 4.12, 4.1, and 4.13). In general, abundant precipitation and organic acids promote chemical weathering; higher temperatures increase chemical weathering rates; temperature extremes promote physical stress on the rock; and cold temperatures are necessary for the formation of ice and, therefore, physical stress within pores and fractures. Regional climatic regimes as well as variations from these norms by way of microclimates would influence conditions at the mineral-scale boundary layer. Weathering environments are susceptible to climate change, as weathering is generally a slow and long-term process.

4.17.3.3 Drainage and Topographic Relief

Both drainage and topographic relief relate to the influx of weathering agents and the removal of solute and solid weathering products. Within the rock or soil, the resident time of reactive chemical agents influences the rate of chemical weathering. Well-drained weathering profiles carry solutes away quickly, but the weathering agents have short contact time. In the same sense, slopes promote the downward movement of weathering products. Steep slopes allow rapid removal of

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material; gentle relief would allow accumulation of weathered material and retention of weathering agents within the colluviums, promoting additional chemical weathering.

4.17.4 Sediment Maturity and Weathering in Transport

Maturity in sediments refers to characteristics of composition, grain size and sorting, and grain morphology, which evolve in a down-path direction from source to end (most often pertaining to fluvial sediments, but equally relevant to aeolian, marine, and glacial sediments). A mature sediment is more exclusively quartz, well sorted, and with greater particle rounding. Weathering, both mechanical and chemical, is a part of this maturation. The works of Krinsley and Mahaney provided extensive discussion of in-transport alterations of sediment grains (Krinsley and Doornkamp, 1973; Krinsley, 1998; Mahaney, 1995, 2002; Mahaney et al., 1996). Although not specifically mentioning weathering or sediment maturity, the comprehensive grain morphology rubric presented by Blott and Pye (2008) permits an organized comparison of factors (such as sphericity, irregularity, and rounding).

It is sometimes assumed for methodological reasons (especially dating methods) that weathering does not take place during sediment transport (cf., Cockburn and Summefield, 2004; Bierman and Steig, 1996). Weathering may be negligible for the purposes of cosmogenic nuclide dating methods, though the impacts are not well researched (cf., McFarlane et al., 2005; Zreda and Phillips, 2000); weathering during temporary storage has been shown to be a significant complicating factor in luminescence dating (Jeong et al., 2007). Weathering can and does occur with sediments in transport, including during temporary storage.

'Comminution', a term used to describe mechanical crushing of sediments in transport, is arguably a weathering process (the "break-down of rock or mineral…"), but is usually not considered as such, *senso stricto*, in that it takes place during transport and not *in situ*. Comminution does produce morphological changes (scars and rounding) and smaller particles (Peterknecht and Tietz, 2011; Wright and Smith, 1993). For sediment (in active transport or in temporary storage), researchers report various means of weathering (Johnsson et al., 1991; Johnsson, 1993; Pye and Mazzullo, 1994; Nesbitt et al., 1996).

4.17.5 Types of Sediment

Huggett (2011) gave a broad classification of 'weathering debris', the products of weathering: solids (detrital particles, including clay, silt, sand, and boulders), solutes (ions in solution), and colloids (clumps of ions combine with organic matter $\sim$1–100 μm). Solutes reappear in precipitated secondary minerals within the weathering system, in cements in sedimentary rocks, or as precipitated sediments (for instance, evaporites or calcium carbonate sediments in oceans and lakes). Solids and colloids become the clastic detrital sediment system, discussed in detail below.

4.17.5.1 Scree (or 'talus') and Other Rock Fragments

Scree properly refers to rock fragments that accumulate at the bottom of a slope (Stratham, 1973), the accumulating depositional slope is known as a talus (Bloom, 1998). (Some authors also refer to talus and scree interchangeably as the particles, and further differentiate scree as the smaller of the particle range.) A wide range of particle sizes occurs, from gravel to large boulders. Ritter et al. (1995: 129) described scree as "controlled by weathering along mechanical discontinuities in the cliff rock…. Therefore, the size of the blocks is largely inherited from the structural characteristics of the parent bedrock". Even so, chemical weathering probably plays a role in rock fabric weakening. Thornburry (1966) recognized the possible importance of mineral hydration in the process of spalling. Granular or gravel-sized scree is probably reliant more on chemical weathering than mechanical, where deep weathering loosens the rock fabric along crystal boundaries (**Figure 3**).

Smaller scree particles are more readily entrained into the sedimentary system, whereas larger blocks would remain stable at footslopes, subject to further weathering (or larger forces of transport, such as glaciers). Boulder- and gravel-bedded streams in steep terrain, as well as the much of the coarse debris entrained in lateral moraines of glaciers are derived from weathering-supplied rock fragments from the surrounding slopes.

Large rock fragments also develop *in situ* in the soil and weathering profile during chemical weathering. Philips et al. (2005) described the prevalence of rock fragments in soil and the importance of lithology, sandstones surviving as fragments preferentially to more weatherable shale. Both down-slope colluvial processes and tree-throw bioturbation are important in the lateral and vertical distribution of rock fragments in the soil. Phillips (2004) also explained particle-size differentiation in soil and weathering profiles. These "vertical textural contrasts", zoned segregation in particle size (coarse vs. fine) that vary by depth, are caused by erosional winnowing or downward translocation of fines from the surface, surface and subsurface inputs of coarse or fine material (by weathering, for instance), and bioturbation.

4.17.5.2 Sand

The dominant mineralogy of most sand is quartz, which is relatively resistant in the weathering environment (though not completely). Sand-sized particles of other mineralogy are also possible, but tend to diminish with sediment maturity (such as feldspars, see above). Sand is derived from crystalline source rocks, or from previously deposited sandstones. In the former, grains are typically coarse, commonly beyond sand-sized, and further weathering or comminution diminishes the size to sand-sized fraction or smaller (Pope 1995a; see also **Figure 4**). Saprolites are an important source of detrital quartz (**Figure 3**). 'Arenization' refers to this process of sand genesis in saprolite, the term literally derived from the Latin (and French, Portuguese, and Spanish) word for sand: *arena* (Sequeira Braga et al., 2002).

4.17.5.3 Silt

A large volume of research literature on production of weathering sediment concerns silt-sized particles. Silt is common

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(a)

(b)

Figure 3 (a) *Gravel scree*. Gravel scree, Gold Camp Road, near Pikes Peak, Colorado. Deeply weathered granite freely disintegrates on an eroded cliff face, accumulating as gravel-sized debris cones at the bottom of the cliff. Photograph by author. (b) *Larger scree slope*. Larger scree slope, with angular clasts dominated by preexisting joint and bedding. Glacier National Park, Montana, Firebrand Pass area. Photo source, P. Carrara, USGS Photographic library. Reproduced from US Geological Survey photographic library, photograph by P. Carrara, ID. Carrara, P. 317 ct. Image file: http://libraryphoto.cr.usgs.gov/htmllib/batch41/batch41j/batch41z/batch41/car00317.jpg

in river sediments, and because it is easily windborne, silt is predominant in loess. The long-standing assumption was that silt occurring in loess was derived from proglacial and periglacial areas during glacial episodes, supported by the occurrence of loess downwind of the glacial limit in Eurasia and North America. Comminution, abrasion (Wright and Smith, 1993), and crushing (Smalley, 1966, 1995; Riezebos and Van der Waals, 1974) do produce silt-sized fragments in quartz, the former evident in the glacial flour that imparts a milky color to proglacial rivers and lakes. Tectonic crushing (Smalley, 1995) was also suggested as a source for silt-sized quartz outside of glacial regions. However, weathering is now recognized as an important source for silt-sized sediments. Wright et al. (1998) compared the various mechanisms possible with laboratory simulations, whereas Wright (2007) provided a comprehensive review of the evidence for weathering-generated silt. In the latter study, Wright pointed out that weathering's role in silt production has been "considerably underestimated", and illustrated a number of examples of weathering-produced silts in glaciated and proglacial environments that predate glaciation. Further evidence of weathering sources include Mazzullo et al. (1988), who identified on the North American continental shelf, preglacial Cenozoic and Precambrian/Paleozoic/Mesozoic silt sediments derived from weathering, in addition to angular silt-sized quartz derived from Quaternary glaciations; and Pope (1995a), who illustrated with electron microscopy a variety of silt-sized particles generated within quartz sand grains.

Dry playas and alluvial plains were assumed to provide the bulk of silt-sized dust in arid and semiarid regions. Again, although silt is plentiful and easily entrained in the wind in drylands, weathering sources are also relevant. Smith et al. (1987) demonstrated the production of silt from quartz sandstone in laboratory simulations of desert conditions. Salt and temperature stress were tested as mechanisms, thus mechanical weathering processes were shown to be important. In the natural environment, Goudie et al. (1979) described the production of silt-sized quartz from salt weathering of dune sands. Dune sands also produce quartz silt by chemical weathering during periods of humid climate (Pye, 1983). In another arid example, Villa et al. (1995) suggested both aeolian and *in situ* weathering origins for fine-grained sediments or 'fissuresols', occurring in rock fractures, depending on the climatic conditions. Chemical weathering would be possible in such fissures during wetter climatic periods. Other examples of chemical weathering production of silt-sized quartz in tropical regions were described by Eswaran and Stoops (1979), Johnsson et al. (1991), and Pye and Mazzullo (1994). Suspended sediment load, both silt and clay derived from chemical weathering, accounts for the pale 'whitewater' characteristic of tropical rivers such as the Amazon and its tributaries (Sioli, 1984).

4.17.5.4 Clay

Clay is a particle size and a class of minerals, and in both cases a possible weathering product. Clay in the sedimentary system is derived from three sources (Eberle, 1984):

1. Inherited from parent material (such as shale or mudstone). Mechanical weathering or abrasion would release

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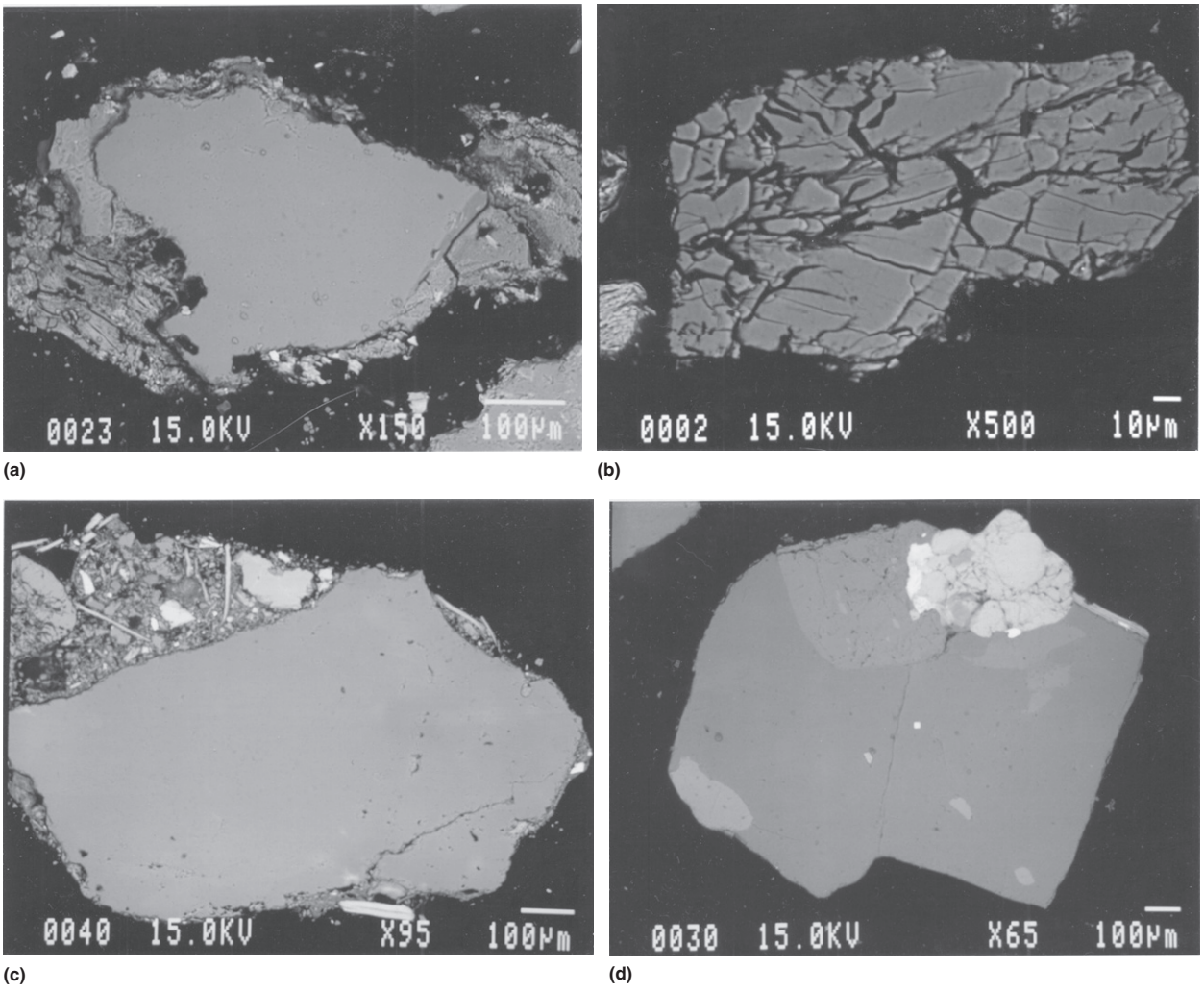

Figure 4 Backscatter electron (BSE) micrographs of sand grains seen in cross section. BSE shading is proportional to the chemistry of the mineral, brighter backscatter corresponds to heavier elements. All samples except (d) are derived from weathered granitic saprolite exposed on marine terraces on the California (USA) coast. Scale differs for each micrograph; scale bar (in micrometers) appears in the lower right in each micrograph. (a) A coarse sand quartz grain, exposed near Montara Beach. The quartz grain is internally sound, with no fractures or grain boundaries, but the edges are disintegrating into smaller particles. (b) A fine sand quartz grain, exposed near Montara Beach. The grain laced with internal fractures or crystal boundaries and is shattered into angular silt- and clay-sized fragments. (c) A coarse sand quartz grain, exposed near Granite Canyon, Carmel, California (USA). The quartz grain is relatively intact except for minor fracturing, but an amalgam of clay- and silt-size particles, possibly a weathering rind, adheres to the upper rim of the grain. (d) Sample from beach sand near Carmel, California, derived from proximal weathered granite. The sediment is immature, evident by the mix of minerals (quartz darkest gray, sodium and potassium feldspars lighter gray) and angularity of the cross section. Weathering is essentially nonexistent on the quartz; the feldspars show minor etching of grain boundaries. All micrographs by author.

clay from parent material to the sediment stream. Inherited clays exhibit little, if any further, alteration and are not usually susceptible to weathering in transport.

2. *In situ* alteration product of weathering (or deep diagenesis) of silicate minerals, such as micas or feldspars (common in igneous and metamorphic rocks).
3. Neoformation, clay minerals precipitated from solution or incorporating amorphous silica. This is also a weathering product, dissolution or solution being an intermediate step. Amorphous silica may come from weathering or directly from volcanic sources.

Clay as a mineral is at or near the end-stage of chemical weathering, and relatively stable (Reiche, 1950). Clay is also relatively stable in terms of erosion, resistant to entrainment, easily carried once transported, and last to drop out of quiet water (Hjuström, 1935). The type of clay formed out of weathering is partially dependent on climatic functions such as temperature and precipitation, though time and parent material are critical and sometimes overriding. Birkeland (1999) provided an overview of climate and clay genesis, but also pointed out where these straightforward relationships do not always follow, for instance, voluminous clay genesis in

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arid and semiarid regions. Clay species can change or modify over climate change. Weathering during extreme events may also alter clay mineralogy: Reynard-Callanan et al. (2010) found that intense wildfires can alter clay minerals in near-surface soil horizons, and that these alterations can persist over several years.

Clay-sized quartz, unlike actual clay phyllosilicate minerals, is similar in nature to fragmented silt-sized quartz, discussed above, though less commonly studied. Leschak and Ferrell (1988) mentioned both pedogenic weathering and glacial crushing origins for clay-sized quartz in suspended sediment of the Mississippi River. Pope's (1995b) nanoscale study of quartz weathering revealed clay-sized (and smaller) fragments of quartz, probably the result of hydration in the crystal lattice.

4.17.6 The Role of Weathering in Cementing Sediment

The processes of chemical weathering liberate ions that, if not carried away in runoff or groundwater, remain in the weathering profile as recrystallized secondary minerals. These weathering products act as indurating cements to detrital particles at or near the surface. Bog iron (cemented by goethite), laterite (cemented by aluminum oxides), and calcrete or caliche (cemented by calcium carbonate) are examples of soils and surface sediments hardened by ions previously in solution. Secondary minerals from precipitated ions are also important at small scales, accounting for case hardening (Viles and Goudie, 2005) as well as infills of microfractures within and surrounding crystal grains (**Figure 4**, and *see* Chapters 4.10 and 4.5). Secondary minerals also play a role in cementing buried sediments. Silica, calcite, iron and aluminum oxides, and clays are all known as cementing agents in sedimentary rocks. The secondary minerals may be derived from surface chemical weathering and work into the groundwater system, or may be derived from diagenetic processes (such as hydrothermal alteration). **Figure 5** illustrates differential weathering due to secondary cementing in arkose, which has indurated specific layers that resist weathering.

Cementing processes may also create aggregate particles. Eswaran and Bin (1977) reported silt- and sand-sized aggregates of gibbsite, halloysite, and kaolinite in deep saprolite in Malaysia, creating anomalously higher proportions of those size fractions.

4.17.7 Summary

Weathering processes are an integral component of the rock cycle, the system of earth materials. Primarily, weathering is responsible for generating clastic sediment and soluble products that cement sediments, and in this process acts as a recycler as important as melting in creating and regenerating rocks. An understanding of weathering processes is important to research in sedimentology, including genesis of sediments, alteration of sediments in transport or temporary storage, and cementing of sediments in the near-surface environment as well as those buried in sedimentary accumulations.

Figure 5 Pinnacles and 'mushrooms' of Dawson Arkose protected by iron-cemented caps, near Colorado Springs, Colorado (USA), in this vintage image from 1914. The arkose itself is an immature sediment product of nearby weathered Pikes Peak granite. Later, weathering of the arkose resulted in kaolinitic decomposition of the constituent feldspars as well as liberation of iron oxides which in turn cemented certain layers, resulting in the pinnacle caps and midpinnacle indurated layers. Photo source: N.H. Darton, US Geological Survey, Plate 12, Folio 203. Reproduced from US Geological Survey photographic library, photograph by N.H. Darton, ID 1055 dnh01055, Plate 12, in El Paso County, Colorado, Folio (Folio 203). Image file: http://libraryphoto.cr.usgs.gov/htmllib/btch329/btch329j/btch329z/btch329/dnh01055.jpg

Both mechanical and chemical weathering processes are active, acting in tandem to weaken crystals and rocks, following paths of least resistance: fractures and joints, bedding and foliation, grain or crystal boundaries, weaker minerals, and internal defects within crystals. All ranges of particle sizes are relevant to the weathering sediment system, from the submicron scale of clay to the meter scale of boulders. Recent research efforts revealed the importance of weathering in the generation of silt- and clay-sized particles that become part of the sediment transport system.

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Biographical Sketch

Gregory Pope is an Associate Professor in Earth and Environmental Studies at Montclair State University in New Jersey. He mentors and teaches undergraduate through doctoral students, undergraduate research and advising foremost in this role. His research interests span soils geomorphology, Quaternary environmental change, and geoarchaeology, working in China, Latin America, Western Europe, and the Western and Northeastern US. He is active in both the Geological Society of America and the Association of American Geographers, and served as Chair of the Geomorphology Specialty Group and a Regional Councilor for the AAG.