
MDAG.com Internet Case Study 23

Rock Grain Size and Its Implications for Minesite-Drainage Chemistry

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Abstract

Kinetically-controlled minesite-drainage chemistry may be determined by, and evolve with, rock grain size and grain-surface area. To our knowledge, there are no detailed monitoring programs of grain-size evolution under full-scale conditions at minesites. Therefore, the current methods to estimate and predict (1) grain size and grain-surface area, and (2) the evolution of these factors in time and space, have inaccuracies on the order-of-magnitude level.

Introduction

An issue that sometimes arises in the interpretation or prediction minesite-drainage chemistry is the grain size of the rock. For example, humidity cells typically contain rock crushed to 6 mm and less, but a full-scale rock pile may contain mostly coarser material. Also, reaction rates can reflect the exposed grain-surface area (e.g., moles/m² of rock-grain surface/wk), rather than the weight of the grains (e.g., moles/kg of rock grains/wk), and this grain-surface area can depend on grain size (e.g., Grain 3.0 at www.mdag.com/grain30.html). Furthermore, geochemical static tests can assume all minerals, like acid-generating sulphide minerals, will be 100% exposed, but this might only occur after long periods of erosion and slaking of rock grains.

So, it seems that rock grain size and surface area can be very important. However, that is not always the case and, when it is, practical issues can raise serious problems.

Equilibrium Conditions

Geochemical kinetic reaction rates can be grain-surface-area dependent. However, at some scale, time, or distance, aqueous concentrations can reach some type of stable, maximum “equilibrium” level, reflecting thermodynamic, meta-stable, or self-organized equilibrium (Figure 1).

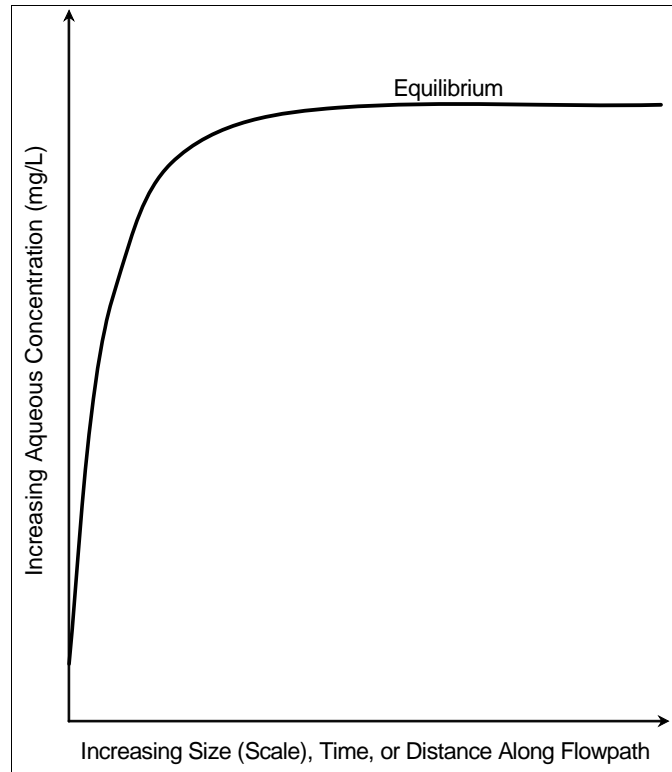


Figure 1. Schematic Diagram of Increasing Aqueous Concentrations to Some Stable Maximum Equilibrium Level with Increasing Scale, Time, or Flowpath Distance.

Under such equilibrium conditions, grain size and grain-surface areas do not directly control aqueous concentrations. Still, grain size can have indirect influences on aqueous chemistry. For example, a coarser grain size could allow faster water movement, reducing residence time (moving to the left in Figure 1), and possibly reducing aqueous concentrations. This coarser-grained example could also have the increased effect of lower reaction rates due to the lower grain-surface area per tonne of rock. In any case, because rock eventually weathers and slakes, grain size would decrease with time and equilibrium may eventually be achieved (moving to the right in Figure 1).

Measurement of Size-Dependent Grain-Surface Area

The understanding and prediction of kinetically-controlled aqueous concentrations (left side of Figure 1) may require the estimation and/or prediction of grain-surface area, among other factors. Grain size is fairly easily and reliably obtained, such as through mechanical sieving, timed settling, or optical scanning.

Grain-surface area is another matter, and there are many ways to estimate it. “Geometric” area can be calculated from grain size and grain shape (e.g., Grain 3.0), from gas adsorption (e.g., BET), or visually (e.g., SEM). The results of these methods can disagree by orders of magnitude, as can repetitive testing of similar samples (e.g., Case Study 5.2.5-1 in Morin and Hutt, 1997 and 2001). Thus, where grain-surface area is important for predicting aqueous concentrations, the presumed inaccuracy or “error bar” should be at least one order of magnitude. This in turn adds significant uncertainty to interpretations and predictions of drainage chemistry.

Evolution of Grain Size and Grain-Surface Area through Time

The dimension of time becomes important for grain-related parameters at minesites. The primary issue is not if a block of rock will weather and erode to fine grains, but how much time is required for this inevitability. In a general sense, temporal plots of grain-size distribution and grain-surface area, over decades to millennia, would be desirable. However, at this time, the evolution of grain size at minesites is a crude estimate at best.

There are simplistic tests, like the Slake Durability Index (SDI). This involves heating of a sample to at least 100°C, which can significantly alter sample mineralogy, then rotating the sample in a partially submerged, 2-mm-mesh-covered cylinder (e.g., Kentucky Transportation Cabinet, 2002). During the rotation, the <2-mm grains breaking from the sample fall through the mesh and are lost. This cycle of heating and wet rotation is often repeated at least twice. The ratio of the remaining weight (e.g., 62 g) to the original weight (e.g., 100 g) is the Slake Durability Index (e.g., SDI = 0.62 or 62%). Thus, the SDI represents the percentage of the original sample that remained inside the mesh cylinder and thus did not slake to a size below 2 mm.

Kolay and Kayabali (2006) measured SDI values for various rock types (Table 1) during four sequential heat-rotation cycles (Figure 2). The vertical extent of a bar in Figure 2 represents the range of SDI values for varying degrees of roundness, with angular grains typically producing the lowest SDI in the range. As the number of cycles increased, the tuff and ignimbrite samples showed the highest amount of slaking (Figure 2), with both generally losing at least 50% of their original mass to slaking by the fourth cycle. The remaining rock types retained at least 70% of their mass after four cycles, except the weathered granite which displayed intermediate slaking.

Kramadibrata et al (2000) reported SDI values for various rock units at an underground coal mine in Indonesia (Figure 3). By the fifth heat-rotation cycle, some units had lost more than 50% of their mass and others had lost less than 40%. This highlighted areas of weak rock in the mine.

One problem with such studies is that the x-axes of Figures 2 and 3 cannot be correlated to specific time periods (months, decades, millennia?). The time periods would be dependent on the physical properties of the rock, water flow rates, and chemical properties of the rock and water (see the next section). While complete slaking is inevitable, the inability to place discrete time periods on these figures weakens their use for predictions of future grain size and corresponding effects on kinetically-controlled drainage chemistry.

<u>Rock Type</u>	<u>Dominant Mineralogy from XRD</u>
Arkose arenite sandstone (Sst-1)	Quartz, feldspar, calcite, clay
Lithic arenite sandstone (Sst-2)	Fragments of andesite and basalt, feldspar, quartz, clay
Weathered granite (WG)	Feldspar, quartz, calcite, clay
Lithic tuff (Tf-1)	Fragments of andesite and basalt, quartz, opal, feldspar, clay
Ignimbrite (Tf-2)	Fragments of andesite, feldspar, clay, quartz
Marl (M)	Calcite, clay
Limestone (Lst-1)	Calcite, clay, fossil
Limestone (Lst-2)	Calcite, clay, fossil

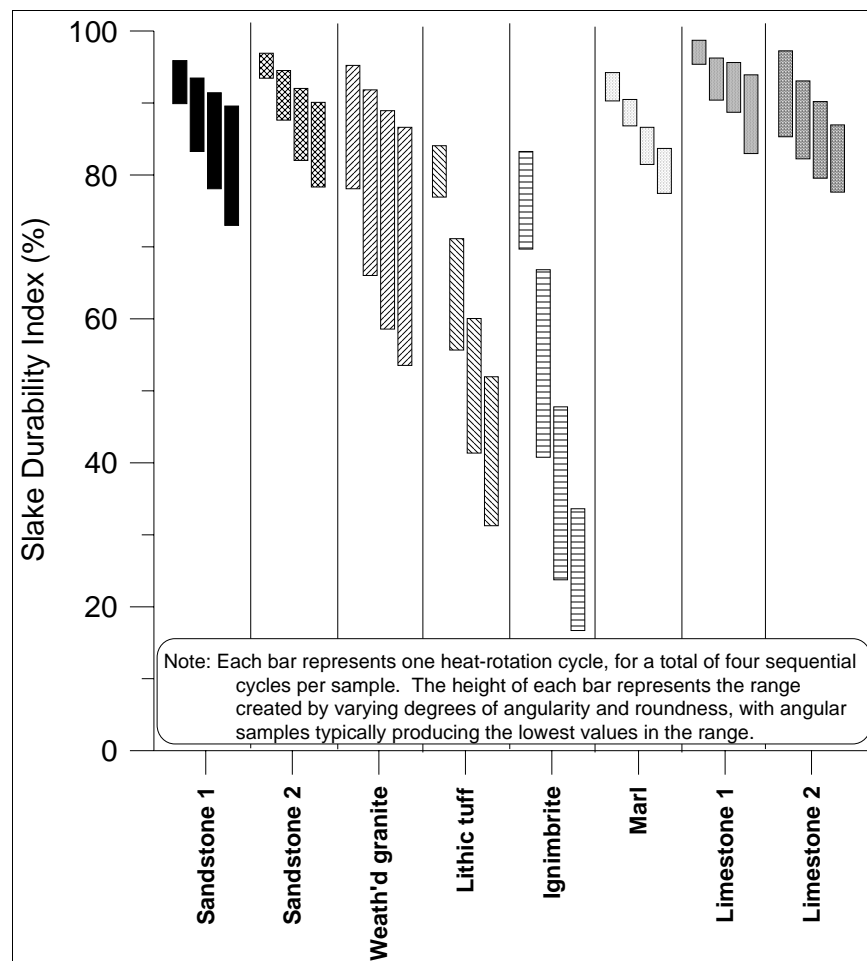


Figure 2. Sequential Slake Durability Indices for Eight Rock Types (data from Kolay and Koyabali (2006)).

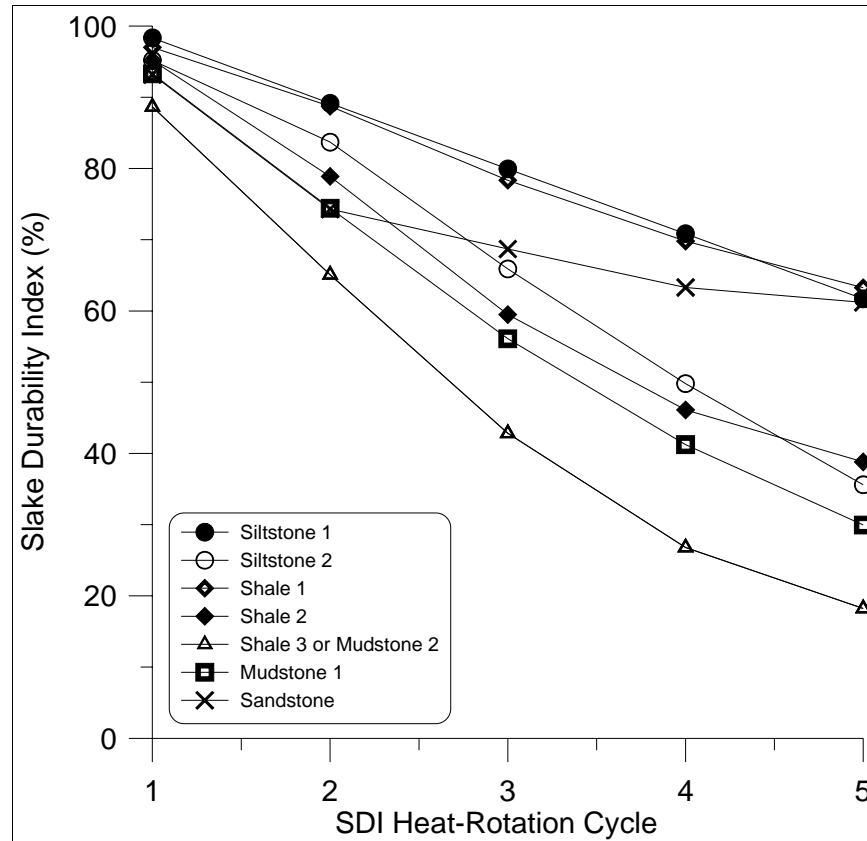


Figure 3. Sequential Slake Durability Indices for Rock Units at an Underground Coal Mine (data from Kramadibrata et al., 2000).

Effect of Chemical Rock Reactivity on Grain Size

Even if time periods could be assigned to the x-axes of Figures 2 and 3, an implicit assumption would be that the rate of short-term slaking would continue indefinitely. In reality, the chemical reactivity of the rock could greatly modify the rate of slaking.

For example, the rate of slaking could accelerate as sulphide minerals oxidize and generate acidity. In Figure 2, exposure to acidic waters would likely accelerate the slaking of the otherwise relatively stable limestone. Also, simple oxidation and weathering, followed by larger-volume secondary-mineral precipitation, can force grains from rock surfaces (Jerz and Rimstidt, 2003) and thus increase slaking.

On the other hand, the rate of slaking could also decrease in the long term. For example, ferric-iron precipitants and encrustations could cover and stabilize rock grains and surfaces.

Conclusion

Under non-equilibrium conditions, the assessment or prediction of minesite-drainage chemistry may require the estimation of temporal changes in grain size and grain-surface area. To our knowledge, there is no such monitoring at minesites under full-scale conditions. Therefore, the current methods to estimate and predict grain size and grain-surface area, and the evolution of these factors in time and space, have inaccuracies on the order-of-magnitude level.

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