Learning Assessment #2 – The Rock Cycle

Note: There are many acceptable ways to format your answer. Below is just one such way. Here we have listed all 8 combinations of changes between the three listed rock types. You did not need to list all 8 combinations for your answer (only 1 from each category), but we list all of them so that you can compare whichever answer you gave with this expert answer.

When comparing Granite (igneous rock), with schist (metamorphic rock), and shale (sedimentary rock), we know that through the rock cycle each one of these rocks can link to the others through certain geologic processes such as erosion, melting and solidification, neocrystallization etc. Also, evidence of these changes can be found in the rock by analyzing the chemical composition, or in some cases, even pre-existing features in the rock that have been preserved. Below are some examples of these processes and the evidence for them:

1. GRANITE to SHALE, GRANITE to SCHIST and GRANITE TO GRANITE

1.1 Granite to Shale: (Igneous to Sedimentary)

Granite forms from solidified silicic magma within the Earth's crust. It can be exhumed (brought toward the surface through erosion of the rock layers above and uplift through faulting). Once the granite is exposed it is subject to weathering and erosion, linking to the sedimentary part of the rock cycle. Physical (breaking apart rock into smaller pieces) and chemical (dissolving mineral ions into a solution) weathering of the granite creates fragments and ions that can be transported through surface sedimentary processes. Quartz minerals from the granite create clastic sediment that plays a key role in the formation of clastic sedimentary rock. Continuous transport of these sedimentary quartz particles can cause quartz to become mud/clay size. The different feldspar minerals, biotite, and amphibole in the granite rock break down to form clay minerals, which can be transported by streams to an ocean environment and eventually deposited with fine (mud/clay sized) quartz as sediment. As this sediment is buried (by more sediment deposited on top), this increases the pressure and temperature and causes lithification (compaction and cementation) of the sediment turning it into shale. For evidence that clasts of shale were derived from a granite, we might try to analyze the bulk rock chemistry of the shale and compare it to the chemical rock composition of granite outcrops that are weathering 'upstream' to see if there is a correlation, however this might be hard to prove. We may also look for rare minerals that are only present in a weathering granite and see if they are present in the shale. These rare /uncommon minerals in sedimentary rock can act like a fingerprint to figure out what rock was eroding to make the sediment.

1.2 Granite to Schist (Igneous to Metamorphic)

Granite can be metamorphosed into schist by the rock being subjected to high enough temperatures and pressures (T/P) such that the minerals in the granite are no longer stable and recrystallize, and new minerals may neocrystallize. This could occur if a granite pluton, sill or dyke is involved in a convergent collision zone (convergent zone between two continental plates) and over time becomes buried deep in the collision zone. The increased T/P will cause neocrystallization, where atoms from minerals, which are not stable at high T/P, form new minerals that are stable. There will also be recrystallization of quartz and feldspar during the metamorphic process. The rock will also become foliated (through the alignment of micas – biotite and possibly muscovite) due to the stresses present during neo- and re-crystallization. Possible evidence for the change from igneous to metamorphic rock could come from analysis of the bulk composition of both rocks. Granite and granitic schist may look different texturally but have a similar chemistry. Granitic schists often look like squashed versions of granite plutons, dykes or sills.

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Granite to Granite (Igneous to Igneous)*

1.3 Granite can be partially or fully melted and then cooled to re-form another granite rock. The melting could be caused by an increase in temperature past the rock's melting point (solidus temperatures) or the addition of volatiles into the rock (which would lower the melting point). Evidence for a granite being formed from a re-melted granite will be hard to find. We can look at the bulk composition of the rock, but this should be the same along with all most other diagnostic properties of the rock because it is essentially the same rock, just reformed.

2. SCHIST to GRANITE, SCHIST to SHALE and SCHIST to SCHIST

2.1 Schist to Shale (Metamorphic to Sedimentary)

Schist can become shale in the much the same way that granite can become shale. It can be exhumed (brought toward the surface through erosion and uplift) and eventually exposed at the Earth's surface. When exposed, physical (breaking apart rock into smaller pieces) and chemical (dissolving mineral ions into a solution) weathering breakdown feldspars, micas, amphiboles, and other minerals in the schist that are not very stable at the Earth's surface. These minerals are weathered into clay, which can be transported by streams and eventually deposited in a low energy environment as sediment. When more sediment is deposited on top, this increases the pressure and temperature and lithifies (compacts and cements) the sediment to form shale. Evidence that this shale was once schist might be found by analyzing the chemical composition of the shale and the composition of of the schist to see if there is a correlation. There may also be uncommon / rare minerals only present in the schist that are found as clasts in the shale.

Schist to Granite (Metamorphic to Igneous)

2.2 Schist can become granite if it is melted. It can be melted as the result of increased pressure and/or temperature, first transforming the schist to gneiss and then migmatite and enough partial melting can generate magma of silicic composition. The addition of volatiles into schist may also lower the melting point of the rock. Evidence of this change will have to come from an analysis of the bulk composition of granite and compare that to schist.

Schist to Schist (Metamorphic to Metamorphic)

2.3 If schist is subjected to a higher temperature and/or pressure (T/P) sometime (millions of years) after the original metamorphism, it can become another schist through neocrystallization (where atoms from minerals which are not stable at high T/P form new minerals that are stable). Evidence for this can be found by observing the mineral assemblages found in the two schists. Also, the older foliation from the first metamorphic event may be preserved during the second phase of metamorphism and two foliations may be present. The higher grade schist will include minerals in an assemblage that are stable at higher temperatures and pressures. The bulk composition of the rock can also be analyzed, keeping in mind that the higher grade schist is probably more dehydrated than the lower grade schist as it was subjected to prograde metamorphism (consistently increasing T/P).

3. SHALE to SCHIST, SHALE to SHALE and SHALE TO GRANITE

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Shale to Schist (Sedimentary to Metamorphic)

3.1 Shale can become schist through neocrystallization (new crystallization of minerals from minerals that are not stable at higher temperatures and pressures) caused by an increase in temperature and/or pressure. This could occur as shale is incorporated into a collision zone and is regionally metamorphosed. Before the shale becomes schist it will go through the transitions of shale to slate, slate to phyllite, and then phyllite to schist. Evidence for this change will include, as in all other cases, an analysis of the chemical (bulk) composition of the rock before and after it became metamorphosed. In addition to the bulk composition, sometimes pre-existing sedimentary features (such as bedding planes or graded bedding) that were present in the shale might be preserved during metamorphism. However, if the schist in question is medium to high grade, then these structures are probably no longer apparent.

Shale to Shale (Sedimentary to Sedimentary)

3.2 Shale can be exhumed (brought toward the surface through erosion and uplift) and eroded by chemical and physical weathering. The sediment can then be transported and deposited in a shale-forming sedimentary environment to once again form shale. Evidence for this change could come from an analysis of the bulk composition of the rock, or an analysis of clasts within the newly formed shale, which have gone through transport twice and may show evidence of this (such as by being composed of a higher abundance of more well rounded clasts).

Shale to Granite (Sedimentary to Igneous)*

3.3. Shale can become granite if it is suddenly melted. It can be melted as the result of a rapid increase in temperature. This could happen if a shale was next to a magma chamber and through the contamination process fragments of shale are incorporated and melted into the magma.

*4. GRANITE to GRANITE and SHALE to GRANITE

These two situations are rare or impossible. Most commonly for granite turn into granite again or shale to turn into granite they would go through metamorphic processes and therefore metamorphic rock first.

However, there are some evidence found in the rock record for sedimentary rock and igneous rock being heated up past it's melting temperature due to rapid heating from magma that has likely risen quickly from depth at very high temperatures and heated the country rock very quickly as well. Evidence for this could be finding an igneous rock adjacent to a sedimentary rock and evidence of very sudden melting and solidification in the adjacent sedimentary rock (i.e. the sedimentary rock has turned to igneous glass right next to the igneous rock). This would be very unlikely with granite as it forms from silica magma, which is typically at lower temperatures. High temperature mafic magma might heat up country rock suddenly and cause that rock to go from sedimentary straight to igneous.

Granite to granite in most conditions found in the Earth's crust would not be possible. Silicic magma, from which granite solidifies forms at lower temperatures' and is unlikely to cause adjacent granite rock to melt suddenly. More commonly, a silicic magma would cause contact metamorphism of older granite it's heating up.