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Greisen

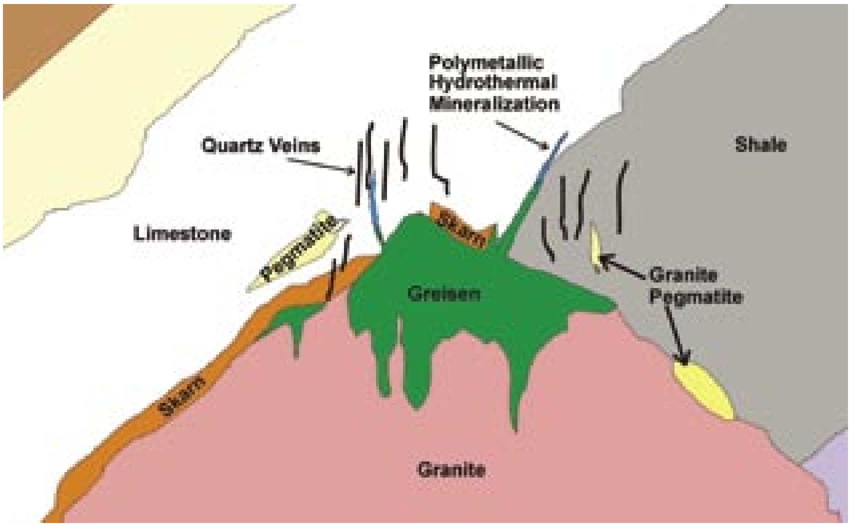

Figure 1. **Schematic of a granite intrusion and associated igneous, hydrothermal, and metasomatc rocks.**

Figure 2. **Topaz and quartz, Schneckenstein cliff, Kielberg Mountain, Klingenthal, Vogtland, Saxony, Germany. Stephan Wolfsried photo.**

In introductory geology, everyone learns the three main rock types: igneous, sedimentary, and metamorphic. There is, however, an entire group of rocks that does not fit well into any of these three categories. These are rocks that form from the precipitation of minerals from hot waters, and they can be classified as the fourth rock type—hydrothermal rocks (Rakovan 2004).

The dissolved constituents that precipitate out of hot waters to form hydrothermal deposits often come from the alteration (involving partial dissolution or leaching) of rocks that come into contact with the reactive hydrothermal fluids. The residual, hydrothermally altered rock is said to be metasomatic (Rakovan 2005). However, in the case of magmatic hydrothermal fluids (i.e., those that exsolve from a melt or magma), most of the dissolved constituents may also come from the magma as a result of the exsolution process. Magmatic hydrothermal fluids may contain comparatively high amounts of light elements (e.g., F, Cl, and S) and heavy elements (e.g., Sn, Mo, W, Au, and Ag) that do not crystallize readily in the common rock-forming silicate minerals that make up most of the solidifying magma (Robinson and Scovil 1994; Evans 1993).

The formation of metasomatic (hydrothermally altered) rocks is usually an intimate part of the process behind the formation of a hydrothermal rock. In disseminated deposits—those in which hydrothermally precipitated minerals are disseminated within small voids or along grain boundaries throughout a host rock—the two make up a single unit. Thus, there may be overlap between metasomatic (a type of metamorphic rock) and hydrothermal rocks in a deposit.

During metasomatism, the resulting mineral assemblage will depend on the chemistry of the protolith (original unaltered rock), the chemistry of the hydrothermal fluid, the amount of water that the rock comes into contact with (i.e., the water/rock ratio), as well as environmental conditions existent during the alteration process (e.g., temperature, pressure, pH, Eh, and so forth). Metasomatic and hydrothermal rocks, like other rock types, are most often classified based on their mineralogy and texture. An important example is known as greisen (pronounced grīz'n).

*Greisen** is a metasomatic-hydrothermal rock that results from the hypogene (Rakovan 2003b) alteration of granite

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*See Rochester Mineralogical Symposium abstract, page 141.

Figure 3. **Cassiterite, 5 × 4 × 3 cm, Horni Slavkov mine (Schlaggenwald), Czech Republic. Photo courtesy of http://www.johnbetts-fineminerals.com.**

Figure 4. **Apatite, main crystal 1.7 cm across, Sauberg mine, Ehrenfriedersdorf, Erzgebirge, Saxony, Germany.**

by fluorine-rich fluids that exsolved from enriched magma during the last stages of solidification. During greisenization, pressure and temperature conditions usually result in a supercritical (gaseous) hydrothermal fluid rather than a condensed liquid phase, but both are possible. In this alteration feldspar- and iron-bearing micas in the precursor granite are converted to a fluorine-bearing mineral assemblage containing primarily quartz and mica (usually muscovite or a Li-mica such as lepidolite), with lesser amounts of topaz. Tourmaline and fluorite may also be major components, and rutile, cassiterite, and wolframite are common accessory minerals. Other accessory minerals that can be found in greisens include molybdenite, arsenopyrite, beryl, bismuthinite, scheelite, axinite, and apatite. The texture of greisens is typically equigranular, somewhat friable, and without a distinct fabric. The term *burr rock* exists in the literature for some intrusion border-zone rocks that texturally look like greisen but are not. It is a superficial similarity but often leads to misidentification.

If present, the accessory mineral constituents can make a greisen economic as an ore deposit, especially for tin, tungsten, or molybdenum. They can be important sources of tantalum and niobium as well. Many tin-tungsten deposits, famous as mineral-specimen producers, are formed in part by greisenization. Greisens are a component of some of the world's most important tin deposits, such as those in Southeast Asia (Malaya, Indonesia, Burma, and Thailand); Tasmania, Australia; the Bolivian tin belt; Cornwall-Devon, southwest England; Panasqueira, Portugal; and Zinnwald and Altenberg (Erzgebirge), Germany. Also, many of the tungsten deposits of southeast China, the richest tungsten province in the world, occur in greisenized granite. Although not commonly described as such in the literature, the mineralization (muscovite, scheelite, cassiterite, beryl, and quartz) of the famous Pingwu mine, Sichuan, China, is very similar to various greisen deposits. In some cases, clay minerals such as kaolinite are formed during greisenization rather than larger mica crystals. Such deposits can be major sources of high-quality kaolin such as the china-clay deposits of Cornwall-Devon, southwest England, which are directly related to the tin greisens of the same area.

The term *greisen* is German and comes from *greissen*, "to split." It was originally used by miners in Saxony with reference to relatively coarse-grained aggregates of quartz and muscovite found on the borders of tin veins in granites of the Erzgebirge, Germany, and the Czech Republic.

Greisen is typically only one part of a much more complex system of rock types that result from the emplacement of silica-rich granitic intrusions (fig. 1). In the final stages of granite crystallization from magma, the last bit of melt becomes very enriched in volatile elements and metals. Depending on the degree of enrichment, the melt may transition to a fluid-dominated system. During this stage of crystallization, pegmatite formation may also occur; pegmatites are often found at the margins of greisen bodies (fig. 1). At some point, fluids may physically separate from the melt and go off to form metasomatic and hydrothermal minerals in the vicinity of the intrusion. Greisen commonly develops at the upper contact of granitic intrusions. Greisen mineralization can be dispersed throughout an altered area of granite. It can also be concentrated along fractures in the granite (as irregular or sheetlike bodies with stockwork zones that extend downward and grade into fresh granite), or greisen mineralization may extend out into rocks surrounding the granite intrusion. In the latter case, the mineralogy may vary depending on the type of surrounding country rock. If they

Figure 5. **Fluorite with zinnwaldite and quartz, 10.2 × 8.2 × 4.2 cm, Zinnwald, Krusné Hory, Bohemia, Czech Republic.**

are carbonate rocks, skarns may also form (Rakovan 2003a). The complex relationships between the alteration products of different rock types and deposition of hydrothermal minerals as well as pegmatite formation can lead to gradations between greisen and pegmatites, greisen and skarns, and greisen veins and hydrothermal vein mineralization of other types (fig. 1). Thus, classic examples may be easily identifiable, but more complex greisens may be difficult to recognize.

Good summaries of the greisenization process can be found in Evans (1993) and Menzies (1995) and a thorough coverage in Scherba (1970). Detailed review of the mineralogy, chemistry, and classification of greisens is given by Stemprok (1987).

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