As an exploration geologist who specializes in metals (gold, silver, copper etc.), I am naturally interested in the metallic mineral resources of Afghanistan. Gemstone deposits are not formed in the same geologic environment as most metallic ores (beryllium, boron, lithium are a few exceptions), but the tectonic juxtaposition of diverse rock types in Afghanistan has positioned metallic ores and gemstone deposits in close proximity. This raises the possibility of exploring for both types of commodities at the same time, with the proceeds of, say, gold and copper exploration, paying the way for gemstone exploration.

The following diagrams were constructed with MapInfo desktop mapping software. Mineral deposit locations (including gemstones) were obtained from Appendix B of Gemstones of Afghanistan by Bowersox and Chamberlin (1995); geologic units were obtained from the USGS Open File Report 97-470C, Map Showing Geology, Oil and Gas Fields, and Geologic Provinces of South Asia (on CD-ROM) by Wandrey and Law; and the shaded relief maps, constructed by Sterner and Rabenhorst, were obtained at the website: www.umbc.edu/ges/afghanistan/afghanistan.html. The book by Bowersox and Chamberlin provides detailed histories of the gemstone deposits, an introduction to the geologic evolution of Afghanistan and the surrounding region, and an extensive list of references.

Figure 1 shows the distribution of igneous rocks in northwest India, Pakistan, and Afghanistan. Other rock units are indicated by but are left uncolored. Because most metallic ores are associated directly or indirectly with igneous rocks, Afghanistan would appear to be a good place to explore, particularly for high-level precious metal deposits such as gold and silver which are associated with younger (Cenozoic-age) volcanic and plutonic rocks. These rocks are a product of the subduction of the Indian craton beneath the European craton beginning about 35 million years ago. The older igneous rocks (Mesozoic and Paleozoic), located primarily in northeast Afghanistan, were formed prior to the Indian craton rifting away from Gondwanaland about 100 million years ago.

The metallic deposits of Afghanistan are not limited to igneous rocks but are found in sedimentary and metamorphic rocks as well. Figure 2 shows that deposits of gold, copper, lead, zinc, and mercury are widely distributed throughout the country. The distribution of copper, in particular, suggests that many deposits are hosted by older sedimentary rocks and are syngenetic in origin; that is, formed in place as the rocks were laid down. Clusters of gold and copper deposits are
found in Tertiary volcanic rocks north of Quandahar and in the province of Badakhshan in the northeastern corner of Afghanistan. Between these areas are a large number of copper deposits located in the vicinity of Kabul. The gemstone deposits are located northeast of Kabul (see below) and were formed in two geologic environments. Ruby, sapphire, and spinel formed during deep burial of sedimentary rocks that were subsequently uplifted and exposed at the surface. Emerald, lapis, and pegmatite-associated gems such as tourmaline, beryl, and spodumene were formed relatively near the surface through the interaction of igneous fluids rich in lithium and beryllium and sedimentary rocks rich in chromium.

The gold and copper deposits north of Quandahar are shown in Figure 3. Gold deposits are distributed along northeast linear trends that parallel the structural grain of the region. Copper deposits appear to occur in clusters, which suggests they are porphyry-related. The occurrence of lead and zinc on the periphery of the copper deposits is another indication that these metals are zoned around igneous intrusions. Mercury deposits are not found in this area, suggesting that the upper parts of the gold deposits have been removed by erosion.

The many copper and iron occurrences near the capital of Kabul are shown in Figure 4. Copper deposits were partially developed by the Soviets during occupation. The hematite iron deposit at Hajji Gak northeast of Kabul is estimated at 1.7 billion tons but is located at over 4,000 meters (13,000 feet) elevation. The proximity of these deposits to Kabul makes them attractive exploration and mining propositions.

The gold and copper occurrences in the province of Badakhshan are shown in Figure 5. Gold placers on found on the western flanks of the mountains. Western mining companies have been active to the north in the Soviet republics of Tadjikistan and Uzbekistan. This area is rugged and is inaccessible much of the year.

The gemstone deposits of are all located within a few hundred kilometers northeast of Kabul, as can be seen in Figure 6. Ruby and sapphire are found at Jegdalek, about 40 kilometers east of Kabul. The ‘ruby’ deposits on the Tadjikistan border with the province of Badakhshan are actually spinel deposits and have not been mined for years. Lapis lazuli is found in southern part of the province near the village of Sar-e-Sung. Emerald is mined in a small area of the Panjshir Valley. Tourmaline, aquamarine, kunzite and other pegmatite-related gemstones are widely distributed throughout the Nuristan region, which consists of the provinces of Konar and Laghman.

The Nuristan area contains many gemstone deposits and, because of its size, has great potential for new discoveries. Some of the deposits are labeled in Figure 7. Much of this area is accessible only by foot.

**Geochemical Sampling**

Areas such as Nuristan will yield new gemstone deposits, and new deposits will be found within established mining areas elsewhere in Afghanistan. Because of high elevation and extreme relief, most of the producing areas are not amenable to classic prospecting. Remote sensing can provide geologic maps, but gemstone deposits are small and can only be located on the ground. It is my opinion that geochemical sampling can provide accurate information on the location of prospective rock formations and the location of actual gemstone deposits.

Gemstones are not typically associated with metallic minerals, so analyses for trace elements on http://www.gems-afghan.com/8-symposium/garylecture.htm
stream sediment or soil samples is not an effective means of finding new deposits. The formation of emerald requires a source of beryllium and ruby and sapphire require a source of chromium, but neither element will be diagnostic of a gemstone occurrence. Gemstones are easily recognizable and are associated with a suite of accessory minerals, which means that the minerals themselves can be used as geochemical pathfinders. Reports on the Panjshir Valley emerald deposits list beryl, tourmaline, and ankerite as accessory minerals, the Nuristan tourmaline deposits are found with black tourmaline, beryl, spodumene, and amphibole, and ruby and sapphires at Jegdalek occur with corundum, garnet, spinel, and pyrite. Lapis is easily recognized because of its bright blue color and has been found with lead, copper, and iron minerals. All of the gemstones and their accessory minerals are readily identifiable in hand specimen and under the microscope. Fragments of tourmaline, beryl, and spodumene in a stream sediment sample would be diagnostic of the geologic environment where these gemstones are found. Splits of the same geochemical samples could be analyzed for metallic elements, such as gold, copper, lead, and zinc, in areas where these types of deposits might occur.

Local people under supervision of western geologists or trained Afghans could carry out geochemical sampling for gemstone and metallic mineral deposits. Several men with horses could make traverses along mountain valleys collecting sub-kilogram-size samples of +20 mesh sediment from every accessible stream and wash. These samples could be flown to a western country for examination or, preferably, preprocessed by locals trained to recognize gemstone minerals under a binocular microscope. Samples containing pathfinder minerals could be ranked and later examined by a trained geologist. This type of program might qualify for international aid.

Mining Operations

Early in my career I worked for several years as an underground miner in Idaho and Tasmania. Although these were modern, well-equipped operations, virtually all equipment ran on compressed air and, in the larger mines, ammonium nitrate and fuel oil (ANFO) was the most used explosive. The gemstone mines of Afghanistan have neither compressed air nor a source of safe explosives (recycled land mines and mortar shells are often used!). I suggest that these two items would substantially improve the safety and efficiency of the gemstone mines, and may be fundable under international aid. A small air compressor can ventilate a tunnel after blasting, or power a single rock drill, a cable and bucket slusher to remove broken rock, or a small rock crusher. ANFO consists of ammonium nitrate fertilizer wetted with diesel oil. It can be prepared onsite and is extremely stable. ANFO is ignited with blasting caps, which are already available in the mining areas.