The Fire of Opal

When one says opal, one thinks immediately of those rare gemstones showing gorgeous flashes of colors as they turn. Opal is actually a very common mineral, but most opal lacks this intense play of colors. What is opal and what causes it to show, from time to time, its colors?

Opal is closely related to quartz in that both are mainly composed of silicon and oxygen. In quartz, the silicon and oxygen atoms are bonded together in a three dimensional orderly pattern forming crystals. In opal, the silicon and oxygen atoms are almost randomly distributed, and no opal crystals exist. The silicon and oxygen atoms in opal do coagulate as tiny spheres ranging in diameter from 0.00001 to .002 inches. The spaces between the sphere are filled with water or air. The spheres look like a bunch of Styrofoarn balls packed together in a glass. The angular holes between the spheres are the pores. If you pour water into the glass it flows readily from pore to pore. Since the water is only loosely bonded into opal's structure, it can leave easily, causing some opals can dry out (dehydrate) and crack.

Quartz and opal are told apart by simple tests. Opal is much softer (H = 5-6 on the Mohs' scale) than quartz (H = 7). Thus some opal can be scratched by a knife blade or nail (H = 5.5) and all of it can be scratched by a streak plate (H = 6.5). Also, if ground up opal is heated in a test tube it will release water vapor that condenses as drops on the cool end of the tube.

The reason opal can show such beautiful plays of color was discovered in the 1970's and well described in the Scientific American article written by an Australian research group (Darragh et. al., 1976). They discovered that in precious opal the silica spheres had a uniform diameter between .00004 and .00007 inches and were stacked up in a regular fashion. Opal lacking a play of colors was either made of larger spheres, smaller spheres or a mixture of sphere of different sizes. This special arrangement of spheres is important because it makes pores of similar size to the wavelengths of visible light. When white light enters opal it is thus diffracted by this regular array of pores and split into colors as though it had entered a prism. Each color has a different wavelength and is split off at a different angle. The particular color we see and, indeed, whether we see any color at all, depends on the angle at which we are holding the opal. This is why the colors change as the stone is rotated. A gem opal commonly shows regions of different colors. This is caused by the presence of regions within the opal where the silica spheres have a slightly different spacing or size, affecting the way the light is split.

When opals dehydrate, they may lose their play of colors and become chalky. This is because the pores in the opal can collapse as the water leaves, messing up the pattern that causes the light to split.

The formation of precious opal rather than common opal requires a precise set of geologic conditions. Darragh et. al. (1976) describe these conditions as " an undisturbed space in a rock holding a clean solution (no clays or salts) of silica from which water is slowly removed over a period of thousands of years". This causes the colloidal silica to slowly grow uniform spherical shells around a nuclei and settle or plate out in a regular fashion. Groundwater moving through porous rocks in a desert could provide such conditions, accounting for the opal fields in the Australian "outback". Slow movements of warm silica-rich water through porous areas in lava flows can also produce gemmy opal such as those from Queretaro, Mexico. Sometimes the gem opal forms in pores in fossil wood such as in the Virgin Valley of Nevada.

Whatever the source, the play of colors of gem opal reminds us of how physics, chemistry and geology unite to form material that human skills can convert to art.
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Reference: Darragh, P.J., A.J. Gaskin and J.V. Sanders, 1976, "Opals", Scientific American, vol. 234 p. 84-95