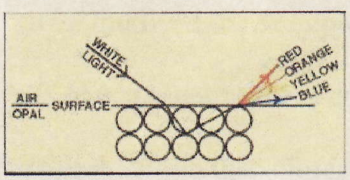
Opal Formation

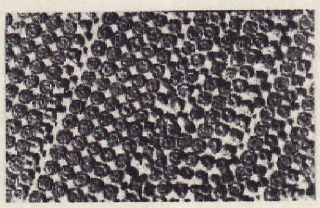
Throughout geological history, the Earth has created some of the most beautiful, valuable, and scientifically puzzling things. From diamond crystals born and spewed forth at extreme temperatures and pressures, to natural gas and oil created by extreme forces of pressure and time, acting on organic materials. It seems that Mother Nature is always willing to astound the human population with the perfection of her creation. One such creation that is an equal marvel to the eye as it is to geological science is that of precious opal. Few other gemstones can attribute their creation to a sedimentary process, and still fewer can account their beauty to a fluke of random symmetry.

Opal can be classified as a non-crystalline form of hydrated silica. Its chemical composition is SiO2.nH2O, water content of opal lies around 3 – 10% by weight but sometimes can reach as high as 20%. On Moh's hardness scale, opal has a hardness of 5.0 to 6.5. Precious opal has a refractive index that lies at 1.450(+. 020, -. 080). Some opal, for example, Mexican Fire opal may have a refractive index as low as 1.37 but typically it ranges 1.42-1.43. The specific gravity of opal ranges from 1.9-2.3. Opal is singly refractive, although it can show anomalous double refraction due to strain.

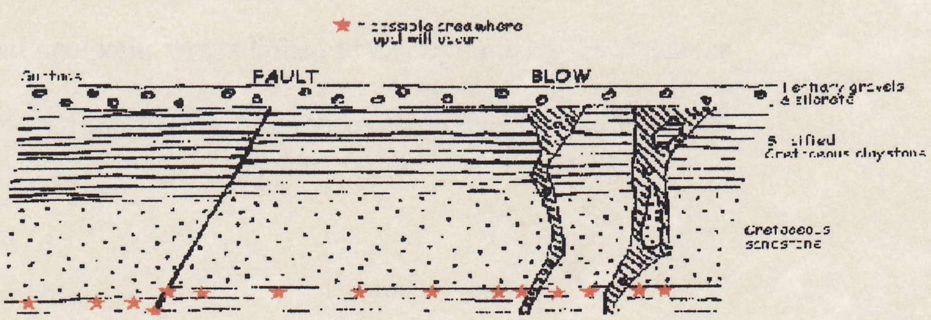
There are many different varieties of opals. In a very basic way opal can be subdivided into that which displays "play of colour" or opalescence, which is generally termed "precious opal," and that which does not. Opal consists of many tiny silica spherules that are arranged together in a 3 dimensional grid. These spheres can range in size and in orientation to each other. In precious opal these tiny almost transparent spheres typically measure with a diameter of less than 1/1000 of a millimeter, and are arranged such that they are all of like size and in even (or near even) rows. The play of colour that precious opal is so well known for is caused by light passing directly through the spheres and is then diffracted at the area where one layer of silica spheres and the next layer meet. The result is the breaking up of white light into its spectral colours, some colours are absorbed others reflected to the eye. It has been discovered that the size of the spheres decides the visible color of the diffracted light. For example large spheres will predominantly exhibit orange and red play of colour, while smaller spheres will display blue and green play of colour.

.





A chemical weathering process followed by sedimentary processes creates the structural phenomena exhibited by opal. There are two predominant geological models by which opal is believed to have been formed. The first, and most widely recognized, model is the "deep weathering" model. This model suggests that amorphous silica is created by the breakdown of feldspar to kaolinite, or smectite to kaolinite. The silica rich water solution created by this deep chemical weathering



then passes through layers of permeable rock until underlying layers of denser, relatively impervious rock finally trap the amorphous silica. With no where to go the silica would be precipitated into voids, cracks and spaces within the host rock. Geologists believe that it is for this reason that opal seems to be oriented around blows and other passageways within the host rock. This theory seems to be supported by much of the vein opal finds throughout Australia.

In recent studies into the nature of silica within water solutions of low temperature some interesting finds have been made. The behavior of silica in solution is still a very persistent riddle to geochemists. When released by weathering silica is soluble in water but it also takes part in many inorganic and biologically mediated reactions that lead to secondary precipitates. It seems that where opal generation is concerned that while low temperature water associated with deep weathering can and does act as a conduit for silica to dissolve and pass through host rocks, it isn't necessarily the final silica involved in the deposition of opal at the end. What this means to the gemmological world is a mere point of curiosity, however to the geological community it is of vast interest. While these finds point at a more convoluted genesis of opal the general mode would seem in agreement with the "deep weathering model" for opal deposition.

The other recognized model for opal formation is quite a new one, into which much research is being done. The "syntectonic (pecover)" model proposes a much more active process which links faults and fissures formation directly to that of opal formation. Basically this model describes a process in which "fault controlled cyclic, fluid pressurized systems which formed opal vein arrays linked to nearby faults."[1] Dr. Pecover believes that opal was deposited very rapidly within fractures created by hydraulic forces coursing through existing faults. The temperatures of these supersaturated fluids were very high (greater than 100 degrees F.) As the system deformed overlying rock beds of sandstone and claystone these hot silica laden fluids were effectively pumped through faults at high forces creating new fractures and depositing opal in areas of lower pressure throughout the system.

Opal found in Brazil is likely to have formed by the syntonic model although older research suggests that two separate systems were involved in the generation of opal and the fractures and voids it fill, new studies indicate that Syntectonics may be responsible. The richest deposits in Brazil are those located in the region of Boi Morto within the municipality of Pedro II, in the Piaui State. "There, basalt sills of the upper Jurassic period intersect slightly inclined sandstone from the Devonian period. Posterior hydrothermal flows of silica loaded water deposited opal in the rocks cracks and crevices."[2] The idea here is that hydrothermal flows of highly pressurized silica laden fluid deposited the opal in fissures already present. However based on the "syntectonic" model it has been suggested that the opal formation in this area likely created new fractures and cracks as well and happened much more rapidly than previously believed.

The behavior of silica in solution at high temperatures is very different from the behavior of silica at lower temperatures. Like most elements silica dissolves much more readily in high temperatures and at a much faster pace than at cold temperatures. Also cooling by a few degrees will lead to dissolution of silica. It is highly possible that within the syntectonic model, which allows for rapid deposition, that the water content of opal can be easily explained. As the silica spheres are deposited rapidly, water remains

---

[1] *Pecover, S. 2001* **Great Australia Basin Abstract**, Department Mineral resources, Sydney, NSW
[2] *Sauer J.R.,* **Brazil Paradise of Gemstones** p 70

bonded to the silica molecule, as new layers are being quickly deposited over top the $H2O$ molecule has no choice but to stay bonded. This could potentially allow for some drastic differences in the appearance of opal formed by the syntectonic model versus the deep weathering model.

One particular type of opal is causing a small stir in the geological community, as there are physical characteristics that are present within the opal which, given the aforementioned opal deposition theories should not be possible. Studies on this material are relatively new and relatively unpublished however the hypotheses of the studies are available for debate. Within the Yowah nut opal, iron ooids, small spherical layered pebbles are believed to have been found. What makes this interesting is that nut opal formation has been attributed much to deep weathering. The ironstone "nuts" or nodes were believed to be ironstone concretions that were filled in with opal as it became trapped against the clay layers. The presence of iron ooids, however, would lead to another possible genesis entirely, as the presence of iron ooids indicates a strictly marine environment. Iron ooids are formed near to seeps and vents within the ocean, where the bi-directional forces exerted by wave action roll a tiny grain back and forth repeatedly. Being situated by seeps iron in solution then is deposited around and around the tiny grains forming concentric layers of iron. If studies can show that the iron ooids were present at the same time as the opal genesis a new model could potentially be on the horizon. Until then our two models will have to be used and extrapolated upon.

Opal is found in many different locales which all have to some degree or another, very different geological environments. This would lead us to the assumption that there are likely many different ways in which opal deposition could occur. What seems to be supporting factor is that there are many different types of opal, and that they all seem to come from different types of host rocks, in very different terrain. Opal genesis is a very complex event. It is likely that one model will never be fully correct, but rather that multiple models will serve, as various methods of deposition are matched with the wide variety of opal.

Sources:

1) **"Exploring and Developing Minerals, Coal, and Petroleum in Queensland, Australia" Department of Mines and Energy, Queensland, Australia, 1990**

2) **"Brazil, Paradise of Gemstones" Sauer, Jules Roger**

3) **"Sedimentary Geology" Prothero, Donald R, WH Freeman and Company, New York, 1996**

4) **"South Australia's Opal" Department of Mines & Energy Staff, Bob Mossel, South Australia, 1989**

5) **"Opal Adventures 2nd Ed." Downing, Paul B. Majestic Press Inc, 1990**

6) **"Opals" Ward, Fred Gem Book Publishers, 2000**

7) **"Gem Reference Guide" GIA Staff GIA, 1993**

8) **"Great Australian Basin Abstract" Pecover, S. Department of Mineral Resources, Sydney NSW, 2001**