FANTASTIC AUSTRALIAN OPALS

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Opal is Australia's national gemstone, yet we do not understand how the economically important precious stones form. Understanding their formation will increase our ability to develop an exploration model to assist the mining industry. So here I shall enlighten you on Australian opals and opal research to date, to gain from you in return, some helpful ideas about how we can increase opal research and in what direction it should go.

Opals have their place in history, associated with the likes of Shakespeare, Napoleon and Queen Victoria. Opal has found a home in the crown jewels of France and in a famous nineteenth century novel which named opal as unlucky for ever. Published scientific opal studies date back to 1854 (Brewster), yet it was not until 1932 with increasing technology that Baier recognised diffraction within opal, which was then further documented by Raman & Jayaraman (1953). Jones *et al.* (1964) showed that precious opal is made up of amorphous silica spheres (0.2-0.5 µm diameter) (Figure 1a) that diffract white light into its component colours or 'play of colour'. Bayliss & Males (1965) noted that the visual difference between common (potch) and precious (gem quality) opal was not related to chemical composition. This led Sanders & Darragh (1971) to show that precious opal has perfectly uniform layered spheres (Figure 1a) compared to common opal, which has irregular and erratically sized spheres within it (Figure 1b). Black opal from Lightning Ridge (Figure 2) has a black base which absorbs most of the white light impinging on it, providing more depth of colour, and increased economic value. More recent works include a molecular analyses by Webb *et al.* (1999) and trace element reports by McOrist & Smallwood (1997). Nonetheless it is still unclear how sedimentary opal forms, with three current formation models delineating three very different processes that form opal in Australia.

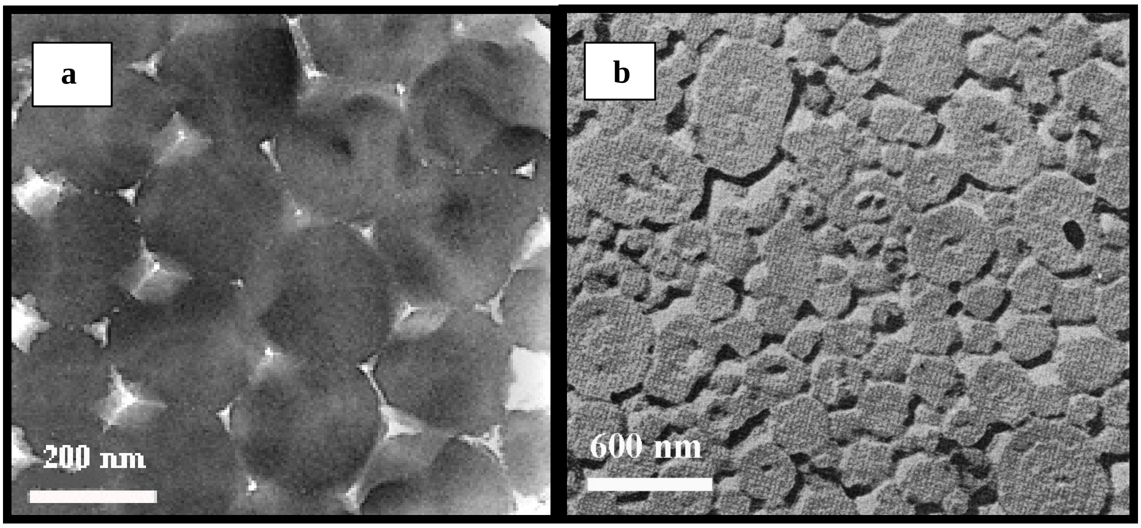

Figure1a (left): Transmitting Electron Microscope image of Silica spheres within a precious black opal, image by John Fitzgerald, RSES, ANU.
Figure1b (right): Potch silica spheres (Sanders & Darragh 1971).

OPAL DISTRIBUTION & OCCURRENCE

Australia is known as the opal capital of the world, with opal is mined from 3 states to date. Other opal producing localities include Mexico, Hungary, Asia, and the United States. All of the significant opal deposits in Australia occur in the Great Artesian Basin (Figure 2). The geology, soil types and resulting vegetation are similar for all Australian opal deposits. Milky-white opals are common in Coober Pedy, White Cliffs and Andamooka; boulder opals are mined in Southern Queensland and black opals are mined at Lightning Ridge. It is unknown whether the different opal forms underwent the same formation processes and if the silica source for each opal type is the same. We need to increase research into Australian opal, to develop exploration tools and further more, better our understanding of silica behaviour within the regolith.

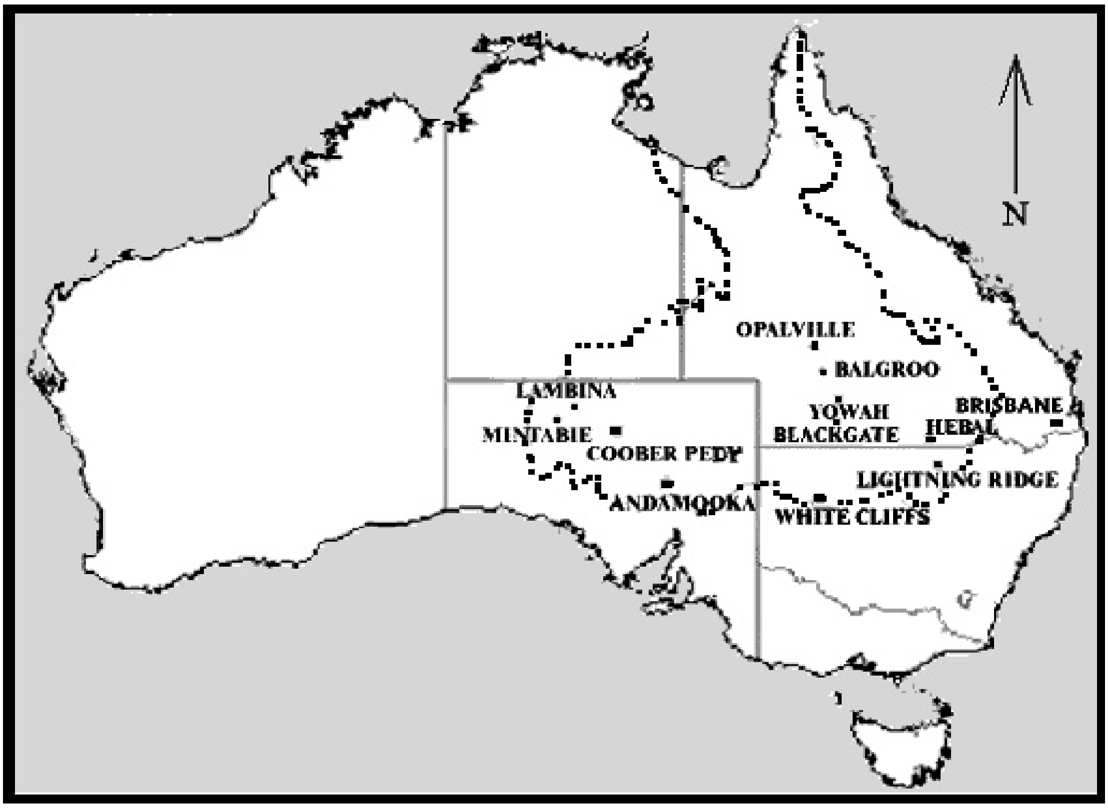

Figure 2: Mined opal fields of Australia. The dashed line represents the Great Artesian Basin boundary.

CURRENT FORMATION MODELS

Several conceptual models have been suggested to explain opal formation. The three dominant postulated models are briefly reviewed here. Under each model are a few examples of implications arising from each model; not all problems are listed.

Weathering Model (Sanders 1964).

Most models describing opal formation within sedimentary rocks consider that the source of the silica is from the host sediment (e.g., Darragh *et al.* 1976, Senior *et al.* 1977, Barnes & Townsend 1982, Watkins 1985, 1999, Robertson & Scott 1990, Townsend 2002). The authors suggest that due to the weathering of silicates within the host sediment, a siliceous solution travelled down the profile and precipitated as a result of evaporation within the underlying claystone. During the Late Cretaceous and Early Tertiary, the opal-hosting areas were subject to intense weathering, causing reactions such as kaolinisation and silica release, giving the conditions necessary for this model.

Problems

A major cornerstone of the weathering model is that opal formed during major weathering events in the Late Cretaceous and Early Tertiary. This, however, would suggest that black opal, for example, would be found all throughout the Surat Basin, not just Lightning Ridge, as the whole area was affected by these weathering events. Lightning Ridge sediments have a trace elemental composition not unlike Taylor & McLennan's (2001) average sediment. Thus there is no rare quality of the opal-hosting sediment in Lightning Ridge that would lead it to produce black opal as a result of sedimentary processes. Stable isotope ratios of Lightning Ridge opal indicate they are not derived from meteoric water, thus opal could not be the result of precipitation from a weathering process. White opal, boulder opal and crystal opal have the same chemistry as black opal. Is there anything unique about the opal host sediments that would cause opal to occur where it does?

Syntectonic Model (Pecover 1996, 1999).

Pecover (1996, 1999) proposed that precious opal was deposited from deeply-sourced hydrothermal fluids. The fluid ascended along faults and silica was deposited actively and rapidly in fractures, at temperatures and pressures well above those typically involved in surfacial processes (> 100 C). The model suggests that the silica-rich fluid precipitated as a result of cooling.

Problems

A lack of alteration within the sediments from ascending fluids is a key indication that the syntectonic theory is invalid. The model also depends upon the connection between breccia pipes and opal, however opal is not always located near breccia pipes. Stable isotope values show that black opal does not require high volumes of water that are associated with hydrothermal systems to precipitate, as evidenced by the low water-rock ratio. Therefore the syntectonic model can no longer be associated with black opal formation. However, even in 2003 the model is still being supported by some researchers.

Cretaceous Microbe Model (Behr *et al.* 2000, Behr 2001).

Communities of soil bacteria and microbes, which are partially preserved in precious opal and potch, were found fossilised in several samples around Lightning Ridge. Thirteen microbe species were identified, including *Myxobacteria, Actinomycetes, Thermoactinomeycetes,* slime moulds, fungi and worms (Behr 2001). These microbes require a nutrient-rich, near-surface environment with temperatures of 23-25°C and a neutral pH. The microbes excreted acids and enzymes that resulted in the biochemical weathering of clay minerals and feldspar. The concept is that most opal nobbies were gas bubbles, originally filled with water, that have been filled with a gel-like solution. Work by Lagaly *et al.* (1999) has recreated this gel-like solution in experiments, which behaved like an agar gel to the micro-bacteria, providing evidence that the microbes thrive in this environment.

Problems

The exact role of microorganisms is unknown; at this stage they could have just eaten their way in after the opal was solidified. Microorganisms can survive at great depths, suggesting that the assumption of a surface environment is not totally valid.

CONCLUSION

Opals are a valuable commodity to Australia and it is clear that further research has to be focussed in this area. The three current formation models of black opal are now predominantly exempt with the introduction of new data so far this year. The real question is, "how do opals form and thus how can we develop an exploration technique to enhance the industry"? Furthermore, how does amorphous silica behave within the Australian regolith? Maybe opal really is unlucky but we won't know without more research!

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