minerals

^{29}Si Solid-State NMR Analysis of Opal-AG, Opal-AN and Opal-CT: Single Pulse Spectroscopy and Spin-Lattice T_1 Relaxometry

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Electronic Supplementary Information

Table S1: Laser Ablation/Ion Coupled Plasma Elemental Analyses (ppm by weight)

		^{27}Al	^{69}Ga	^{31}P	^{23}Na	^{39}K	^{85}Rb	^{133}Cs	^{24}Mg	^{43}Ca	^{88}Sr	^{137}Ba
Opal-AG												
	G1401	6.58E+03	2.62E+00	3.12E+00	9.42E+02	1.08E+03	1.23E+01	2.38E+00	3.23E+02	2.42E+03	7.92E+01	1.55E+02
	G9811	5.99E+03	2.61E+00	3.54E+00	9.75E+02	1.25E+03	1.08E+01	2.94E+00	1.63E+02	2.08E+03	9.08E+01	1.54E+02
	T2233	6.11E+03	2.73E+00	3.91E+01	8.05E+02	2.07E+03	1.09E+01	1.83E+00	1.88E+02	1.45E+03	4.68E+01	1.44E+02
	G8608	4.56E+03	1.36E+00	3.53E+00	1.01E+03	8.11E+02	1.31E+01	2.82E+00	1.37E+02	9.27E+02	3.36E+01	8.38E+01
Opal-AN												
	E1937	5.19E+00	3.02E-02	3.29E+00	5.55E+00	2.10E+00	1.22E-02	0.00E+00	2.28E+01	3.62E+01	1.96E-01	1.22E-01
	MS-4	6.42E+00	2.59E-02	3.55E+00	6.12E+00	1.39E+01	5.99E-02	5.88E-04	7.09E+01	8.25E+01	3.60E-01	2.27E-04
	G32740	8.10E+00	2.06E-02	8.43E+00	7.78E+00	1.08E+01	1.57E-01	1.85E-03	1.01E+01	1.30E+02	1.82E-01	1.81E-01
	M8736	3.57E+00	1.01E-02	3.33E+00	8.09E+00	3.32E+00	1.16E-02	0.00E+00	2.74E+01	3.52E+01	1.38E-01	4.38E-03
	OOC10	4.58E-01	8.92E-03	3.30E+00	6.17E+00	8.83E+00	4.09E-02	8.69E-03	5.57E+01	6.29E+01	4.55E-01	1.39E-01
	T18511	8.93E-01	1.79E-02	3.34E+00	5.30E+00	6.92E+00	5.31E-02	5.75E-03	5.18E+00	3.26E+01	1.36E-01	1.27E-02
	T18117	1.60E+01	1.38E-01	5.11E+00	4.76E+02	6.04E+01	2.81E-01	9.78E-02	9.08E+02	1.46E+03	1.52E+01	9.85E-01
	G7107	2.26E+01	1.08E-01	4.78E+00	5.10E+00	1.17E+01	7.04E-02	4.09E-04	3.42E+01	9.71E+01	4.56E-01	2.57E-02
	G8877	2.73E-01	6.69E-03	3.35E+00	3.62E+00	1.03E+01	6.03E-02	3.33E-03	6.68E+01	8.81E+01	5.02E-01	2.51E-02
	G13764	3.13E+00	6.16E-02	3.16E+00	1.91E+00	1.07E+01	6.99E-02	0.00E+00	7.26E+00	2.56E+01	9.16E-02	2.44E-03
Opal-CT												
	G9942	2.98E+01	1.63E-01	3.93E+00	4.58E+01	6.28E+00	6.39E-02	2.13E-02	5.53E+01	4.79E+01	3.80E-01	6.00E-02
	ETH S2	6.76E+03	1.25E+00	2.86E+00	2.98E+02	9.66E+02	1.46E+01	1.38E+00	1.28E+02	4.00E+03	3.51E+01	2.56E+01
	GNEW03	3.64E+03	1.45E+00	4.30E+00	9.47E+02	2.25E+02	3.82E-01	3.95E-02	1.16E+03	5.23E+02	7.93E+00	1.96E+00
	OOC3	4.32E+03	2.49E+00	1.66E+01	1.62E+02	2.55E+03	1.06E+01	2.00E-01	6.51E+02	1.60E+03	1.83E+01	6.04E+00
	T22842	3.71E-01	2.24E-02	5.84E+00	4.29E+01	1.54E+01	9.34E-03	2.53E-04	2.94E+01	1.23E+02	6.52E-01	9.96E-01

		^{49}Ti	^{51}V	^{55}Mn	^{57}Fe	^{59}Co	^{60}Ni	^{65}Cu	^{66}Zn	^{89}Y	^{90}Zr	^{139}La	^{178}Hf
Opal-AG													
	G1401	6.83E+00	7.01E-02	9.17E+00	4.85E+02	1.09E-02	6.94E-02	2.88E-02	2.12E-01	7.07E-01	6.66E+01	6.20E-01	2.24E+00
	G9811	5.30E+00	8.96E-02	5.50E+00	3.93E+02	1.39E-02	5.66E-02	2.67E-02	6.63E-02	2.32E-01	9.07E+01	2.39E-01	2.60E+00
	T2233	7.22E+02	4.76E+00	1.85E+01	1.04E+03	5.00E+01	1.73E+01	1.59E+02	1.53E+01	1.00E+01	1.90E+02	1.37E+01	4.79E+00
	G8608	8.36E+00	8.95E-02	5.30E+00	2.71E+02	5.53E-02	1.00E-01	1.46E-01	4.47E-01	3.73E-01	8.03E+01	3.68E-01	2.41E+00

Opal-AN													
	E1937	1.28E-01	3.47E-01	2.61E-02	2.20E-01	3.61E-03	2.36E-02	9.03E-03	5.52E-02	6.03E-03	5.81E-02	1.59E-04	1.83E-04
	MS-4	2.07E-02	4.95E-01	3.22E-02	0.00E+00	0.00E+00	3.55E-03	0.00E+00	3.06E-01	7.96E-03	2.28E-02	1.12E-04	3.90E-04
	G32740	6.33E-01	4.58E-01	1.22E-01	6.30E+00	2.74E-02	1.59E-01	5.47E-01	5.31E-01	4.69E-03	6.28E-02	4.53E-03	4.05E-03
	M8736	9.34E-03	4.34E-01	2.40E-02	0.00E+00	0.00E+00	1.92E-02	7.57E-03	7.72E-02	4.41E-04	1.75E-03	1.04E-04	1.47E-04
	OOC10	6.02E-03	2.33E-01	2.47E-02	0.00E+00	8.83E-04	2.17E-02	2.24E-02	3.61E-01	7.10E-03	1.28E-03	1.68E-04	0.00E+00
	T18511	1.09E-02	4.17E-02	2.72E-02	0.00E+00	0.00E+00	3.43E-03	2.43E-03	5.68E-02	1.49E-02	2.05E-03	6.70E-04	4.52E-04
	T18117	2.14E-01	1.50E-02	7.14E+00	4.11E+00	2.60E-02	7.05E-02	2.49E+00	9.91E-01	3.02E+01	1.18E-02	4.49E-01	1.10E-03
	G7107	3.52E-01	5.78E-01	5.26E-02	2.31E+00	7.50E-04	2.21E-02	3.76E-02	1.14E-01	5.20E-03	2.11E-02	5.73E-03	1.32E-03
	G8877	6.54E-02	7.75E-01	2.59E-02	0.00E+00	1.77E-03	1.86E-02	2.77E-02	3.97E-01	2.26E-03	4.70E-04	3.04E-04	6.96E-05
	G13764	4.03E-02	4.66E-02	3.28E-02	0.00E+00	0.00E+00	2.00E-02	2.81E-02	7.83E-02	2.75E-03	6.13E-04	3.18E-04	1.25E-04
Opal-CT													
	G9942	2.70E+00	3.48E-01	2.67E-01	5.43E+01	2.38E-02	9.51E-02	1.24E-01	1.77E-01	6.33E-03	4.09E-02	1.14E-03	4.34E-04
	ETH S2	4.68E+01	5.36E-04	1.71E+01	7.24E+02	1.84E-02	2.26E-02	2.08E-02	1.55E+00	5.26E+00	3.78E+01	2.49E+00	1.25E+00
	GNEW03	3.30E-01	8.04E-01	2.43E+00	1.75E+04	1.14E+00	9.62E+00	8.85E+00	2.28E+01	1.62E-01	1.34E+01	1.02E-02	2.47E-02
	OOC3	7.43E+02	5.74E+01	1.51E+00	1.10E+03	6.49E-01	7.23E+00	8.28E+00	4.84E+00	5.38E-01	2.11E+01	1.84E+00	6.17E-01
	T22842	8.29E-02	2.24E-01	1.37E-01	2.01E+02	4.22E-03	7.48E-02	3.06E+00	1.20E+00	1.95E-02	3.24E-02	5.74E-03	1.61E-04

		^{140}Ce	^{141}Pr	^{146}Nd	^{147}Sm	^{151}Eu	^{153}Eu	^{157}Gd	^{159}Tb	^{163}Dy	^{165}Ho	^{166}Er	^{169}Tm	^{172}Yb	^{175}Lu
Opal-AG															
	G1401	1.33E+00	1.44E-01	6.16E-01	1.22E-01	4.32E-02	4.49E-02	1.23E-01	1.64E-02	1.01E-01	2.08E-02	5.83E-02	8.19E-03	5.09E-02	7.39E-03
	G9811	4.64E-01	4.82E-02	2.01E-01	3.69E-02	1.18E-02	1.37E-02	3.76E-02	4.75E-03	3.05E-02	6.70E-03	1.82E-02	2.39E-03	1.44E-02	2.11E-03
	T2233	3.22E+01	3.48E+00	1.33E+01	2.67E+00	7.93E-01	7.93E-01	2.20E+00	3.24E-01	1.87E+00	3.69E-01	1.04E+00	1.49E-01	1.02E+00	1.49E-01
	G8608	9.49E-01	1.05E-01	4.42E-01	8.92E-02	2.85E-02	2.69E-02	7.97E-02	1.07E-02	6.43E-02	1.31E-02	3.59E-02	4.89E-03	3.31E-02	4.93E-03
Opal-AN															
	E1937	3.37E-04	9.44E-05	3.77E-04	1.16E-04	4.71E-05	3.73E-04	5.35E-04	1.15E-04	7.61E-04	7.64E-05	4.44E-04	2.56E-04	1.60E-03	3.60E-04
	MS-4	2.40E-04	2.64E-04	2.07E-04	3.71E-04	7.89E-05	2.93E-04	1.64E-04	1.02E-04	7.68E-04	3.52E-04	7.26E-04	3.40E-04	4.83E-03	1.08E-03
	G32740	1.66E-02	2.02E-03	7.56E-03	2.25E-03	1.19E-03	1.06E-03	2.42E-03	3.77E-04	3.38E-03	1.01E-03	1.02E-03	9.79E-04	1.77E-03	9.11E-04
	M8736	6.07E-04	1.51E-04	1.34E-04	1.39E-04	3.07E-05	3.24E-04	3.17E-04	3.41E-04	3.35E-04	2.39E-04	4.56E-05	1.24E-04	3.67E-04	7.43E-05
	OOC10	4.03E-04	1.91E-04	1.97E-04	6.20E-04	8.84E-05	4.73E-05	8.50E-04	1.47E-04	4.41E-04	1.10E-04	4.13E-04	1.02E-04	3.24E-03	6.98E-04
	T18511	1.19E-03	3.34E-04	1.37E-03	9.83E-04	1.04E-04	1.11E-04	1.32E-03	3.03E-04	1.84E-03	4.97E-04	1.55E-03	3.42E-04	4.17E-03	8.55E-04
	T18117	8.43E-02	8.45E-02	3.82E-01	2.91E-01	6.63E-02	6.45E-02	1.01E+00	2.56E-01	2.03E+00	4.43E-01	1.44E+00	2.21E-01	1.38E+00	2.02E-01
	G7107	2.03E-02	2.07E-03	6.25E-03	2.02E-03	2.78E-04	8.81E-04	7.32E-04	2.93E-04	1.84E-03	3.26E-04	1.07E-03	9.93E-05	1.36E-03	9.59E-05
	G8877	9.79E-05	1.04E-04	1.48E-04	2.55E-04	9.60E-05	4.21E-05	5.27E-04	4.27E-05	3.25E-04	2.71E-04	1.93E-04	1.22E-05	2.09E-04	1.02E-04
	G13764	6.96E-04	1.69E-04	6.24E-04	6.69E-04	3.95E-04	7.26E-05	2.52E-04	1.72E-04	5.43E-04	7.52E-05	4.56E-04	9.15E-05	5.81E-04	2.63E-04
Opal-CT															
	G9942	1.80E-03	3.52E-04	1.21E-03	5.16E-04	2.59E-04	1.01E-04	4.97E-04	7.87E-05	8.80E-04	7.96E-05	7.23E-04	4.10E-05	8.21E-04	1.64E-04
	ETH S2	7.19E+00	5.22E-01	1.83E+00	5.23E-01	2.82E-02	2.78E-02	5.84E-01	1.29E-01	9.15E-01	1.87E-01	5.48E-01	7.81E-02	5.85E-01	8.51E-02
	GNEW03	2.15E-02	5.99E-03	3.60E-02	1.11E-02	4.09E-03	4.04E-03	1.84E-02	3.03E-03	2.28E-02	5.50E-03	1.81E-02	3.05E-03	2.26E-02	3.38E-03
	OOC3	3.88E+00	4.22E-01	1.62E+00	2.98E-01	8.16E-02	8.10E-02	2.17E-01	2.96E-02	1.58E-01	2.78E-02	7.10E-02	9.25E-03	5.87E-02	7.81E-03
	T22842	1.51E-02	1.93E-03	9.20E-03	2.78E-03	5.27E-04	5.61E-04	3.51E-03	4.99E-04	3.01E-03	7.66E-04	2.07E-03	4.31E-04	4.47E-03	8.37E-04

		^{206}Pb	^{207}Pb	^{208}Pb	Σ Pb	^{232}Th	^{238}U
Opal-AG							
	G1401	4.20E-03	3.46E-03	8.54E-03	*1.62E-02*	6.66E-02	2.65E-02
	G9811	4.70E-03	3.81E-03	9.75E-03	*1.83E-02*	7.81E-02	2.65E-02
	T2233	7.19E+00	6.00E+00	1.50E+01	*2.82E+01*	6.93E+00	2.36E+00
	G8608	6.99E-03	5.63E-03	1.43E-02	*2.69E-02*	1.47E-01	5.72E-02
Opal-AN							
	E1937	2.17E-03	1.02E-03	1.86E-03	*5.04E-03*	2.12E-04	2.98E-01
	MS-4	4.94E-04	2.05E-04	3.73E-04	*1.07E-03*	9.82E-05	1.35E-01
	G32740	6.12E-02	5.08E-02	1.22E-01	*2.34E-01*	4.70E-03	3.40E-02
	M8736	4.43E-04	5.99E-05	7.75E-04	*1.28E-03*	9.55E-05	1.16E-01
	OOC10	3.29E-02	1.83E-03	9.99E-04	*3.57E-02*	5.33E-05	1.52E+01
	T18511	4.42E-02	2.49E-03	2.85E-04	*4.69E-02*	1.70E-04	2.49E+01
	T18117	1.00E+00	7.71E-01	1.87E+00	*3.65E+00*	4.26E-03	5.48E+01
	G7107	1.94E-03	1.88E-03	4.21E-03	*8.03E-03*	1.35E-03	5.29E-02
	G8877	1.95E-03	3.03E-04	7.86E-04	*3.04E-03*	2.37E-04	3.81E-01
	G13764	1.40E-03	4.20E-04	7.19E-04	*2.54E-03*	1.48E-04	2.95E-01
Opal-CT							
	G9942	9.39E-04	7.89E-04	1.58E-03	*3.31E-03*	3.99E-03	8.74E-02
	NMNHETH S2	5.40E-01	4.58E-01	1.16E+00	*2.16E+00*	1.21E+00	7.81E-01
	GNEW03	3.13E-02	2.78E-02	6.68E-02	*1.26E-01*	1.77E-02	2.12E-01
	OOC3	1.19E-01	9.83E-02	2.44E-01	*4.62E-01*	2.99E-01	3.46E-01
	T22842	8.82E-02	7.86E-02	1.84E-01	*3.51E-01*	2.55E-03	2.17E+01

S2: Additional Spectra and Delay Time Relaxation Plots

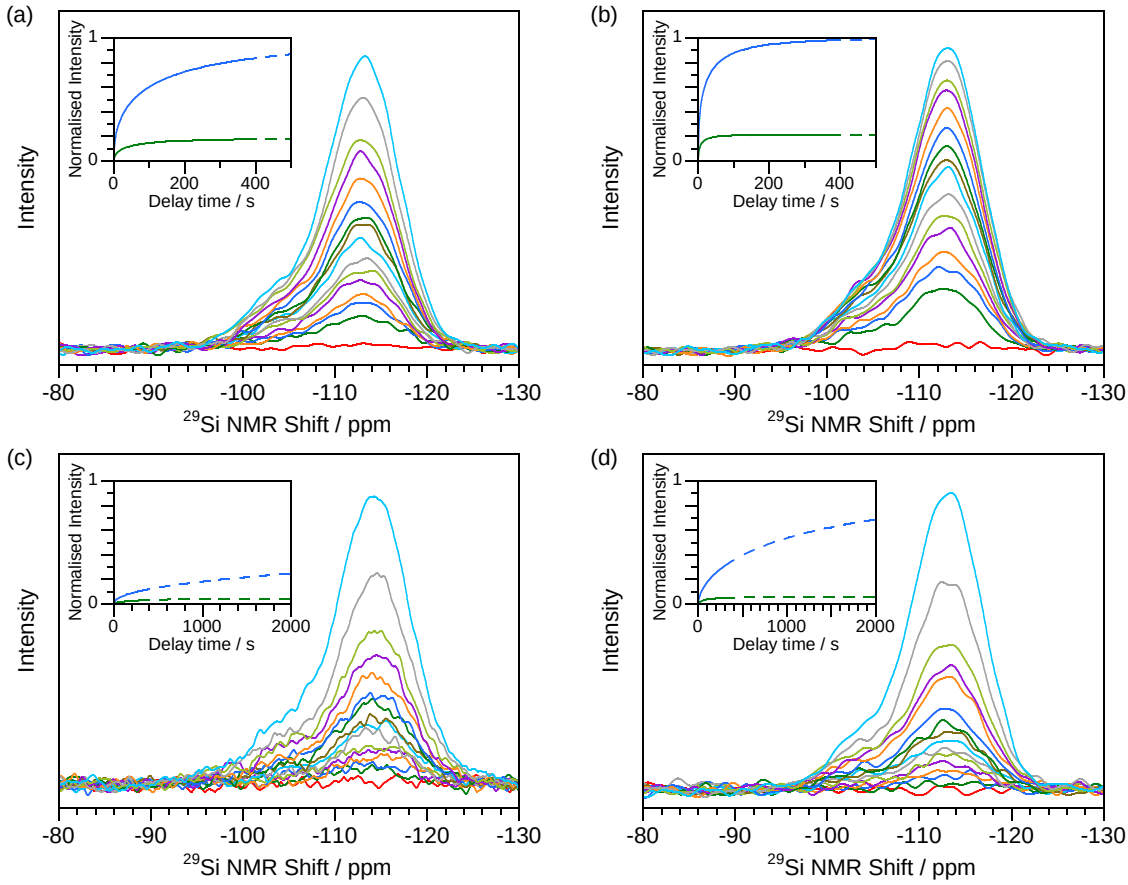

Figure S1. Evolution of the spectrum with delay time for (**a**) a translucent zone in G34475 (hydrophane opal (opal-A) from Dubnik, Slovakia), (**b**) an opaque zone in G34475, (**c**) "Spanish menilite" (GNEW23 from Caldes de Malvella, Spain), and (**d**) Gilson synthetic opal. Delay times are 1, 2, 3, 5, 7, 10, 15, 20, 25, 35, 50, 75, 100, 200 and 400s (with the zero-time measurement shown in red). Insets are calculated fitting of Q_3 (green) and Q_4 (blue) components using data in Table 1 and scaled to Q_4 maximum.