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A PRELIMINARY U-Pb DATE ON CAVE SPAR, BIG CANYON, GUADALUPE MOUNTAINS, NEW MEXICO, USA

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U-Pb dating of a football-sized, dogtooth spar, calcite crystal collected from a cave in Big Canyon, Guadalupe Mountains, New Mexico, USA, gave an age estimate of 87 - 98 Ma for calcite deposition. This Upper Cretaceous (Laramide) date is important because: (1) it implies that there may have been a major karsting episode in the Guadalupe Mountains in the Laramide; (2) it implies that the Laramide was a time of heating and deeply circulating hydrothermal water; (3) it relates to the possible time of regional uplift above sea level of the Guadalupe Mountains along with the rest of the western United States; and (4) it relates to a time of possible hydrocarbon maturation and migration in the Delaware Basin.

Spar (or “geode”) caves are lined with dogtooth and/or nailhead spar calcite crystals. In the Guadalupe Mountains, these can be small, individual caves or small to large rooms intercepted by later, larger, sulfuric acid cave passages. They can range from a few meters up to tens of meters or more in size, but most are (on the average) about 5 m. From fluid-inclusion temperature data (~30-85ºC), spar crystals in the Guadalupe Mountains are known to have precipitated from low-temperature hydrothermal water (Crysdale 1987; Hill 1987). Hill (1996) thought that spar in Guadalupe caves was Miocene (Basin and Range) because isotopically similar spar fills Basin and Range fault zones along the western escarpment of the Guadalupe Mountains.

The spar sample dated in this study (Sample 97CAH) was collected from a small (12 m long x 2 m wide) cave located in Big Canyon, Guadalupe Mountains (Fig. 1). It is a “football”-size crystal 40 cm long and 18 cm in diameter (at its center) that grew as a single crystal over time, from inside outward. The outermost 1 cm of the crystal is an opaque, white crust, probably the result of sub-aerial weathering, but its bulk interior consists of tight, inclusion-free, translucent calcite that can be assumed to have functioned as a system closed to any infiltration or leakage after its precipitation.

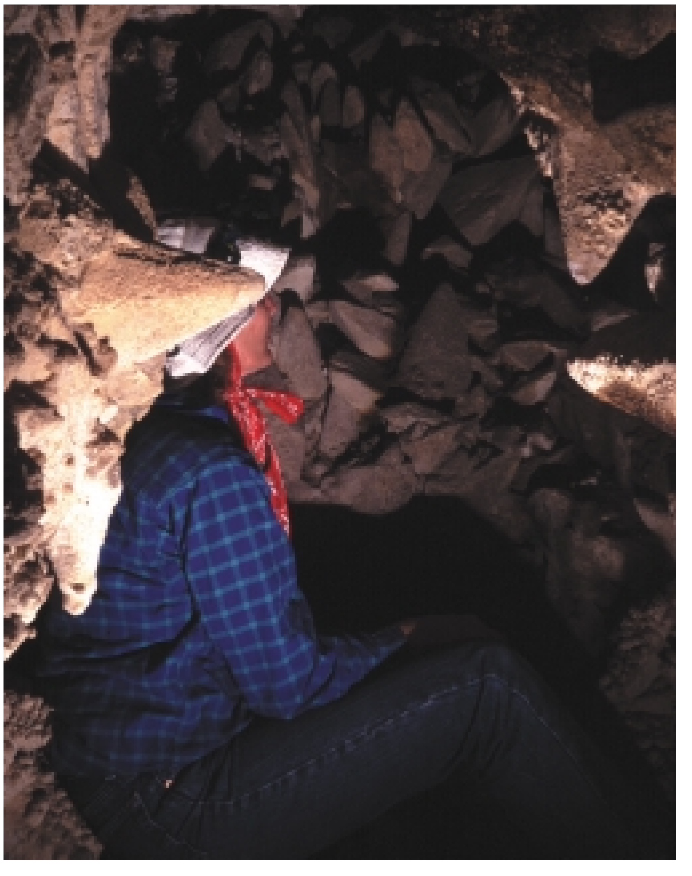

Figure 1. Dogtooth spar crystals lining a small "geode" cave in the area of Big Canyon, Guadalupe Mountains. Some of the spar crystals are as large as footballs. Photo by Alan Hill.

U-PB ANALYSES

In principle, the decay of ^{238}U to stable ^{206}Pb (and the decay of the rare isotope, ^{235}U to ^{207}Pb) function as chronometers that can be applied to all kinds of cave calcites. However, there has been little application of this method in karst studies hitherto because Pb is very widespread in nature and it is difficult to find speleothem samples that do not have significant amounts of it (common Pb) incorporated into the growing calcite; this background “noise” masks the U-Pb decay signal in perhaps the majority of instances. This serious problem can sometimes be avoided by working with calcites that display big variations in U content from point to point. This causes the ratios of parent ^{238}U or daughter ^{206}Pb to non-radiogenic ^{204}Pb ($^{238}U/^{204}Pb$; $^{206}Pb/^{204}Pb$) in a sample to vary: the slope of the line drawn through a plot of results from varying sub-samples establishes the age (Ludwig 1977). For reviews of U-Pb dating of secondary calcites in caves and elsewhere see Smith *et al.* (1991) and Richards *et al.* (1996).

Two sets of three sub-samples of ~0.5 gm each were taken at intervals of 3-4 cm from the center to the inner (unweathered) edge of the crystal. In a clean room at McMaster University, the samples were dissolved and passed through ion exchange columns in 0.7M HBr form and the Pb extracted with 6M HCl. The U fraction was processed through a 7.5M HNO_3 column and extracted with 0.7M HBr. Isotopic ratios were measured by thermal ionization mass spectrometry on a VG 354 machine with a Daly detector in peak jumping mode. The Pb fraction was loaded with silica gel and run at 1400ºC, and corrected for fractionation using measured ratios from the NBS981 standard. The U fraction was run on a double filament, correcting for fractionation by using the average fractionation factor measured in natural uranium runs on the mass spectrometer during the preceding year. One of the central sub-samples failed to run. The analytical data for the remaining five sub-samples are given in table 1.

RESULTS

The mean age of the Big Canyon spar sample calculated with the $^{238}U/^{206}Pb$ dating equation is 91.3 Ma, plus or minus a two standard deviation error margin of 7.8 Ma. The age obtained with the $^{235}U/^{207}Pb$ equation we calculated conservatively as 108±46 Ma; Urs Klötzli, a U-Pb dating specialist who refereed the work, derived a more precise estimate of 95±7.3 Ma from our data. The lower intercept on a simple $^{207}Pb/^{206}Pb$ v. $^{238}U/^{206}Pb$ concordia plot yields an age of 86±12 Ma; using the calculated ratios of common Pb in the sub-samples to refine the isochron regression Klötzli obtained a more reliable lower intercept of 90.7±2.8 Ma.

It will be seen that these five age estimates are very close together, placing within one standard deviation of each other. Thus, the arithmetic mean age of spar sample 97CAH can be placed between 87 and 98 Ma with confidence. Because of the common Pb problem, it is probably infeasible to determine the difference in age between the oldest and youngest parts of the crystal; however, from the isochrons, this is likely to be much less than the range of 11 million years cited above.

DISCUSSION

The Upper Cretaceous date on the Big Canyon cave spar is important that these are the first "hard" data that specifically relates to Laramide events in the Guadalupe Mountains. Since the spar lines cave passages, it implies that spar caves are also at least this old; that is, there was possibly a major karst episode in the Guadalupe Mountains in the Laramide. This makes sense since a major uplift of an area should initiate karst dissolution in carbonate rocks. If this date is correct, then it strongly suggests that at least some spar-lined cave passages formed much earlier than has previously been supposed.

Fluid-inclusion temperatures of the spar also suggest that Guadalupe spar caves were formed by hydrothermal water. This in turn implies that a magmatic heat source existed below the Guadalupe Mountain-Delaware Basin area in the Laramide, and may have been responsible for regional uplift. This same heat source could also relate to the maturation and migration of hydrocarbons, and answer some pertinent questions concerning the timing of oil and gas migration into some of the big fields of the Delaware Basin area.

From an inter-regional perspective, this new information on the possible timing of the Guadalupe Mountain uplift may also relate to the "Alvarado Ridge" – a postulated north-trending Laramide continental arch that extended from Mexico to Wyoming (Eaton 1987). Thus, this one date reaches beyond purely speleogenetic considerations.

CONCLUSIONS

The U-Pb date adopted here should be considered preliminary for two reasons:

(1) Only one U-Pb date has so far been obtained on a spar crystal from a Guadalupe cave.

(2) It now appears from these very limited data that there may be (at least) two spar depositional episodes in the Guadalupe Mountains: one of Laramide age and one of Basin

Table 1. U-Pb analytical data for speleothem 97CAH.

Sub-sample	U (ug/g)	Pb (ug/g)	$^{238}U/^{204}Pb$	$^{206}Pb/^{204}Pb$	$^{235}U/^{204}Pb$	$^{207}Pb/^{204}Pb$
97CAH-FT	2.03±0.66*	0.11±0.29*	1504±0.7*	37.58±0.25*	10.91±0.69*	16.29±0.26*
97CAH-FM	0.22±0.62	0.13±0.17	101±0.7	19.10±0.14	0.73±0.68	15.30±0.14
97CAH-FB	0.07±0.62	0.52±1.43	7.3±1.4	17.06±1.22	0.05±1.37	14.48±1.10
97CAH-08	0.73±0.66	0.02±0.12	3725±0.7	70.43±0.11	27.02±0.73	17.88±0.13
97CAH-04	0.70±0.62	0.04±1.14	1219±1.3	32.54±1.00	8.84±1.28	16.13±1.10

* all error margins are quoted to two standard deviations.

and Range age. Spar crystals from other caves should now be dated to establish whether the cave spar linings are all of Laramide age.

Considering the importance of this one date to the understanding of regional, petroleum, and speleogenetic events, it is hoped that this dating program can be continued in the future.

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