TIMING OF BRITTLE DEFORMATION IN THE CAÑON CITY EMBAYMENT, CO, BY LA-ICP-MS U-PB DATING OF CARBONATE VEINS: A FEASIBILITY STUDY

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INTRODUCTION

- ❑ The Colorado Front Range and its tilted sections of sedimentary rocks are one of the most iconic geological features within the United States. Extensive sections of Paleozoic to Mesozoic units are exposed in the Cañon City embayment (Fig. 1). Tilting and formation of the embayment is the result of the late Cretaceous Laramide Orogeny. Further uplift of the Rocky Mtns. occurred during Neogene times (e.g., Karlstrom et al. 2012)
- ❑ This study tests the feasibility of U-Pb carbonate dating of brittle deformation features in the Colorado Front Range, specifically in the Canon City embayment. We hypothesize that these are associated with Front Range uplift.
- ❑ Samples from fault surfaces were collected in the Temple Canyon area (Ordovician Harding Fm.), the Harding Fm. along Shelf Road, and the Marsh-Felch Dinosaur Quarry area (Jurassic Morrison Fm.) (Fig. 1). The latter site yielded famous dinosaur specimen, e.g., the Stegosaurus at the Smithsonian Museum.

Cañon City Embayment

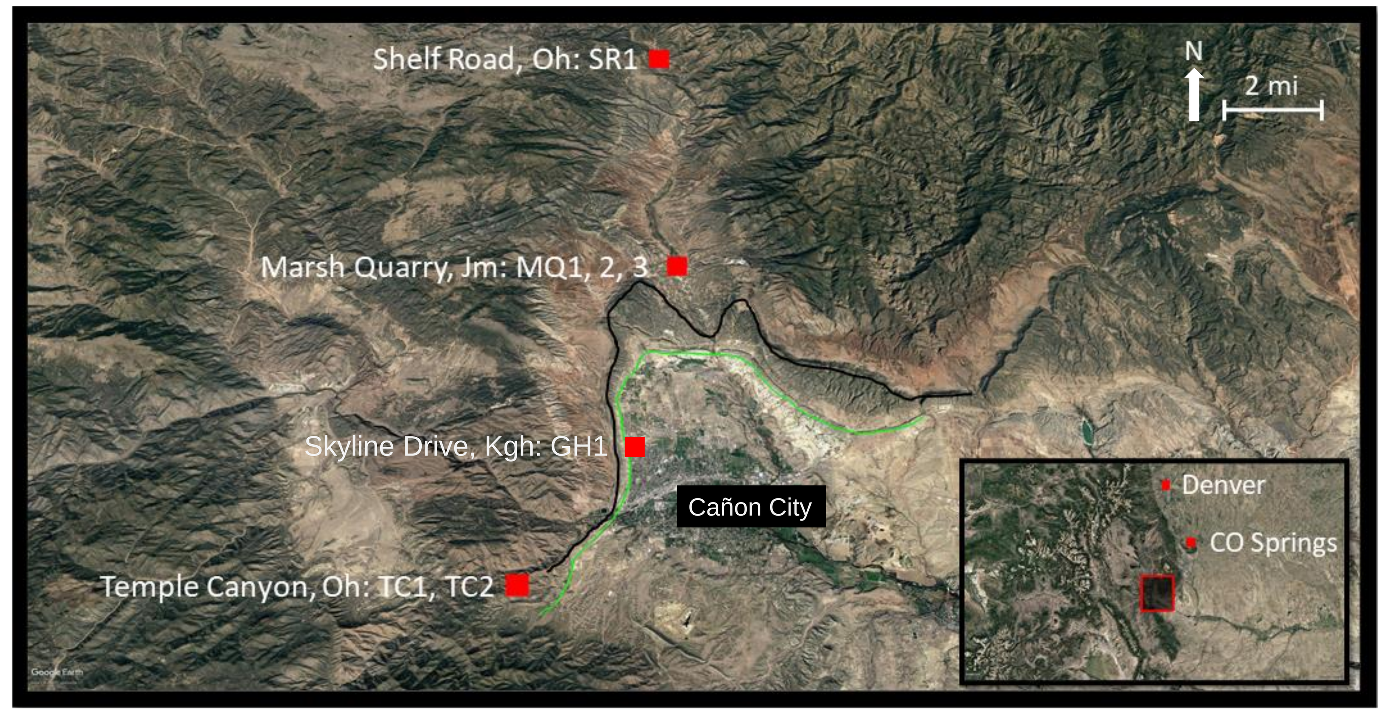


Fig.1: Satellite view of the Cañon City, CO area from Google Earth with sample locations. Steeply dipping Cretaceous Dakota Sandstone (Kd) outlined in green highlights the Rocky Mountain Front Range around the city. Red squares highlight sample locations, labeled with sample identifier. Overview map outlined in white shows the Rocky Mountain belt with research area outlined in red.

METHODS

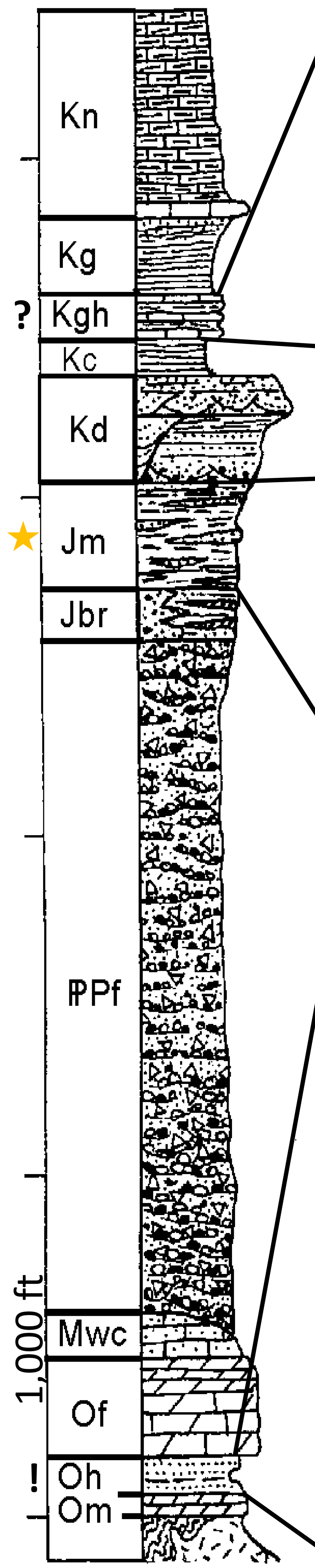
U-Pb isotopes were analyzed in polished thick sections (ca. 100 µm) and unpolished surface samples of carbonate veins by laser-ablation ICP-MS at the University of Kansas, using a Photon Machines Analyte.G2 193nm excimer laser and Thermo Element2 mass spectrometer. Pb isotope fractionation was calibrated to NIST614 glass, U-Pb fractionation was corrected using reference material DBTL *Hill et al. (2016) and validated with WC1 (Roberts et al., 2017)

REFERENCES

Hill, C.A., Polyak, V.J., Asmerom, Y. & P. Provencio, P., 2016. Tectonics 35(4), 896-906.

Roberts, N.M., Rasbury, E.T., Parrish, R.R., Smith, C.J., Horstwood, M.S. & Condon, D.J., 2017. Geochemistry, Geophysics, Geosystems 18(7), 2807-2814.

Karlstrom, K.E., Coblentz, D., Dueker, K., Ouimet, W., Kirby, E., Van Wijk, J., Schmandt, B., Kelley, S., Lazear, G., Crossey, L.J. and Crow, R., 2012. Lithosphere, 4(1), p.3-22.



Adapted from Emmett Evanoff, 1996, modified 2006

OUTCROP DOCUMENTATION

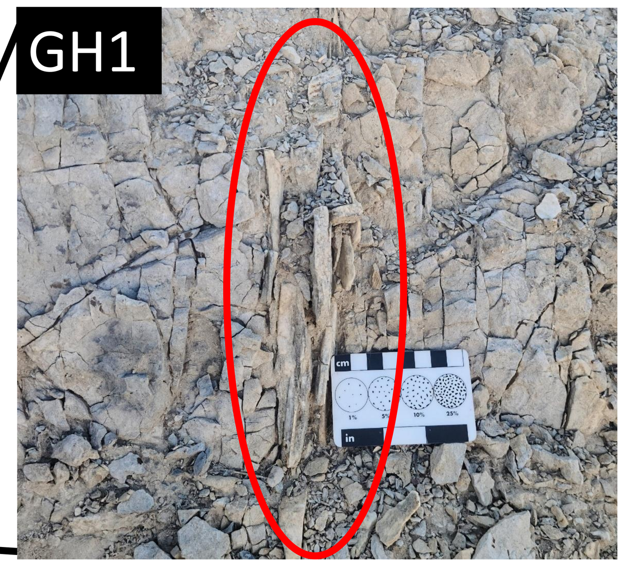


Fig.5: Carbonate vein cross cutting the Cretaceous Greenhorn Fm, a limestone dominant unit just east of Skyline Drive, CO.

Fig.4: Carbonate-filled veins at the Marsh-Felch quarry in the Jurassic Morrison Fm. Pink over-grows a white vein generation representing multiple fluid flow events.

Fig.3: Carbonate slicken fibers along a fault surface in the Ordovician Harding Fm, a quartz rich sandstone unit in the Temple Canyon area.

Fig.2: Carbonate slicken fiber sample along another fault surface in the Harding Fm collected along Shelf Road, CO. Sample collected is outlined in red.

SAMPLE DOCUMENTATION

Fig. 5a: Close up image of the carbonate vein sample collected from the Skyline Drive area. Striations appear to be perpendicular to the strike of the beds.

Sample is currently being prepped for analysis.

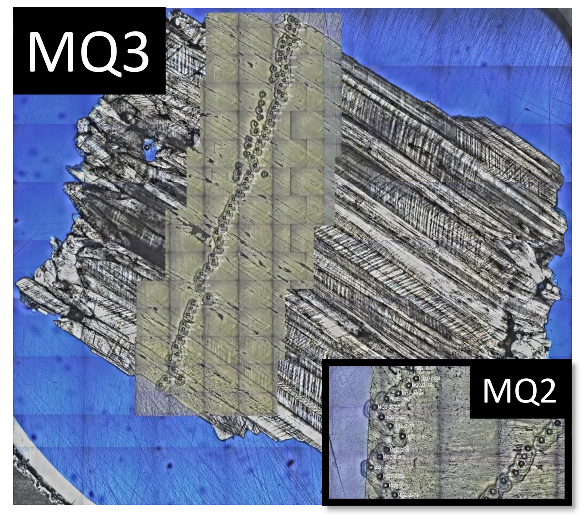


Fig. 4a: Transmitted light image of fibrous calcite growth for sample MQ3. Overlain is a reflected light image showing the traverse of laser spots (130µm diameter). Bottom Right: transmitted light image of MQ2 with traversal of same spot size

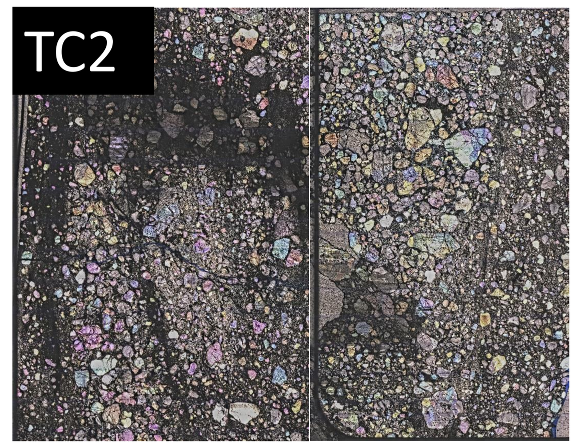


Fig. 3a: Transmitted light image of TC2 showing rounded quartz clasts that make up the Harding sandstone. Dark areas represent the fine calcite cement or slicken fibers that were too fine to ablate for analysis.

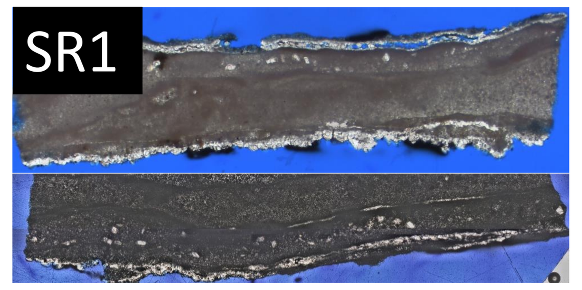


Fig.2a: Polished mount in reflected light. Carbonate material visible on top and bottom of the sample as bright layers, and in scattered grains throughout the vein.

Fig.2b: Left: Surface sample in holder with museum wax. **Right:** reflected light image showing surface ablation.

U-Pb LA-ICP-MS RESULTS

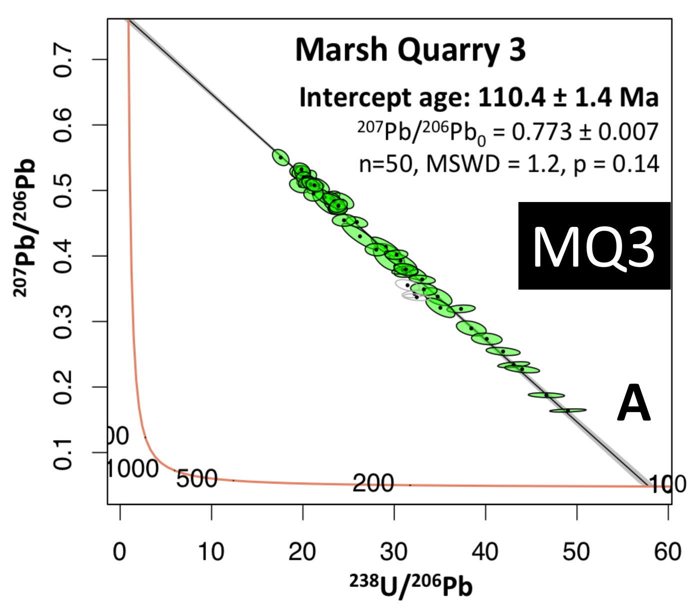


Fig.4b: precise age of 110 Ma for MQ3. Small ellipsoids represent low uncertainties with respect to the x and y-axis.

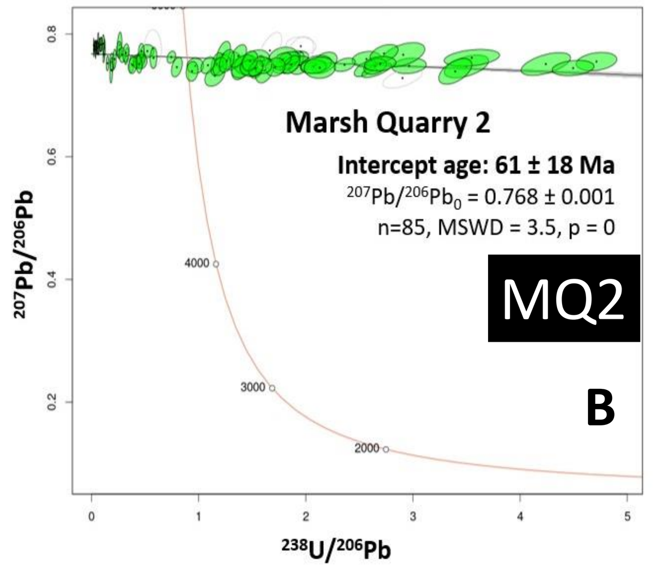


Fig.4c: limited spread in U-Pb gives imprecise Laramide age of vein MQ2-2, consistent with field evidence (Fig. 4).

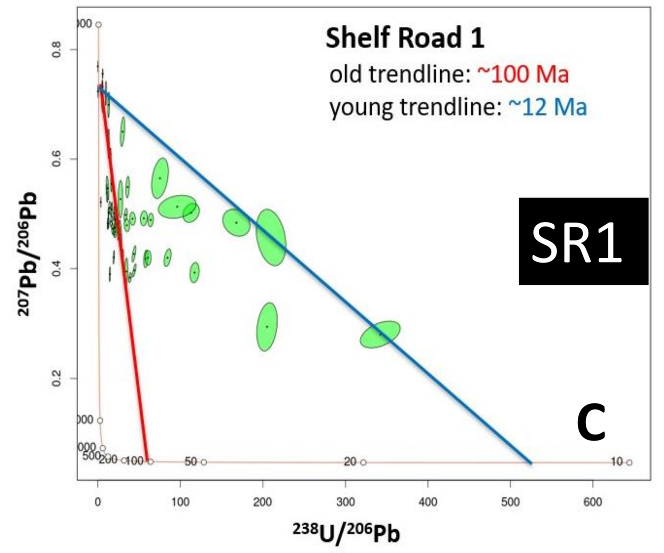


Fig.2c: Scattered U-Pb data of SR1 indicating even ts between >100 Ma and 12 Ma.

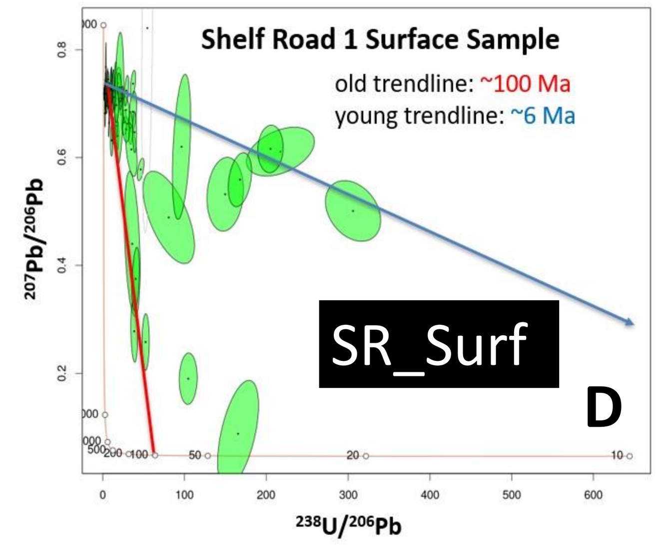


Fig.2d: Surface analyses of SR sample yields a similar range, but youngest array indicates a ca. 6 Ma event.

CONCLUSIONS

- ❑ U-Pb carbonate results range from Cretaceous to Neogene.
- ❑ A precise date of 110.4±1.4 Ma from a 2 cm-wide carbonate vein in the Jurassic Morrison Fm. coincides with basin formation and the Sevier Orogeny, predating Rocky Mtn. uplift and Laramide deformation. This is contrary to the initial hypothesis.
- ❑ A younger vein-fill from Jm yields data with higher uncertainty, consistent with Laramide deformation.
- ❑ Carbonate-filled fracture in the Ordovician Harding Fm. Along Shelf Road gives scattered data, interpreted as result of multiple fluid-flow events from Cretaceous (basin formation) to Neogene (Rocky Mtn. uplift) times. Compositionally, veins in the Harding are likely less suitable to use for analysis in comparison with veins from units with a higher number of silts & shales.
- ❑ A more detailed study over a wider range of units along the Front Range will explore the deformation history further e.g., Greenhorn Fm in progress

DATA REPORTING TABLE

Laboratory & Sample Preparation	
Laboratory name	KU Isotope geochemistry laboratory
Sample type/mineral	carbonate
Sample preparation	polished section, epoxy impregnated
Imaging	flourescence
Laser ablation system	
Make, Model & type	Arf excimer 193 nm, Photon Machines Analyte G2, ATL
Ablation cell & volume	Helex 2, two-volume cell
Laser wavelength (nm) / pulse width (ns)	193 / 5
Fluence ($J.cm^{-2}$)	2.7
Repetition rate (Hz)	10
Spot size (um)	130 (circular spot)
Carrier gas / sample gas	He, 1.01 l/min, Ar, 1.1 l/min
Ablation duration (secs)	30
ICP-MS Instrument	
Make, Model & type	Thermo Element2 magnetic sector field ICP-MS
RF power (W)	1100
Detection system	single detector, counting & analog
Masses measured	206Pb, 207Pb, 208Pb, 232Th, 238U
Integration time per peak (ms)	5-10 ms
Total integration time per reading (secs)	184
Total method time	47
IC Dead time (ns)	6
UO+/U+ (%)	<0.2
232Th+/238U+	0.8
Data Processing	
Gas blank (s)	17
Calibration strategy	NIST 614 for Pb calibration, drift etc., DBTL for U-Pb
Reference materials	NIST 614 (Jochum et al. 2009), DBTL (Hill et al. 2016)
Data processing package used / Correction for LIEF	IGOR PRO, Iolite 2.5
Common-Pb correction	none
Quality control / Validation	WC1 (Roberts et al. 2017)

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