AN IN-SITU Rb-Sr DATING & LIFE DETECTION INSTRUMENT FOR A MER+ SIZED ROVER: A MSR PRECURSOR

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Constraints

- Mission concept must address competing scientific, political, and fiscal requirements:

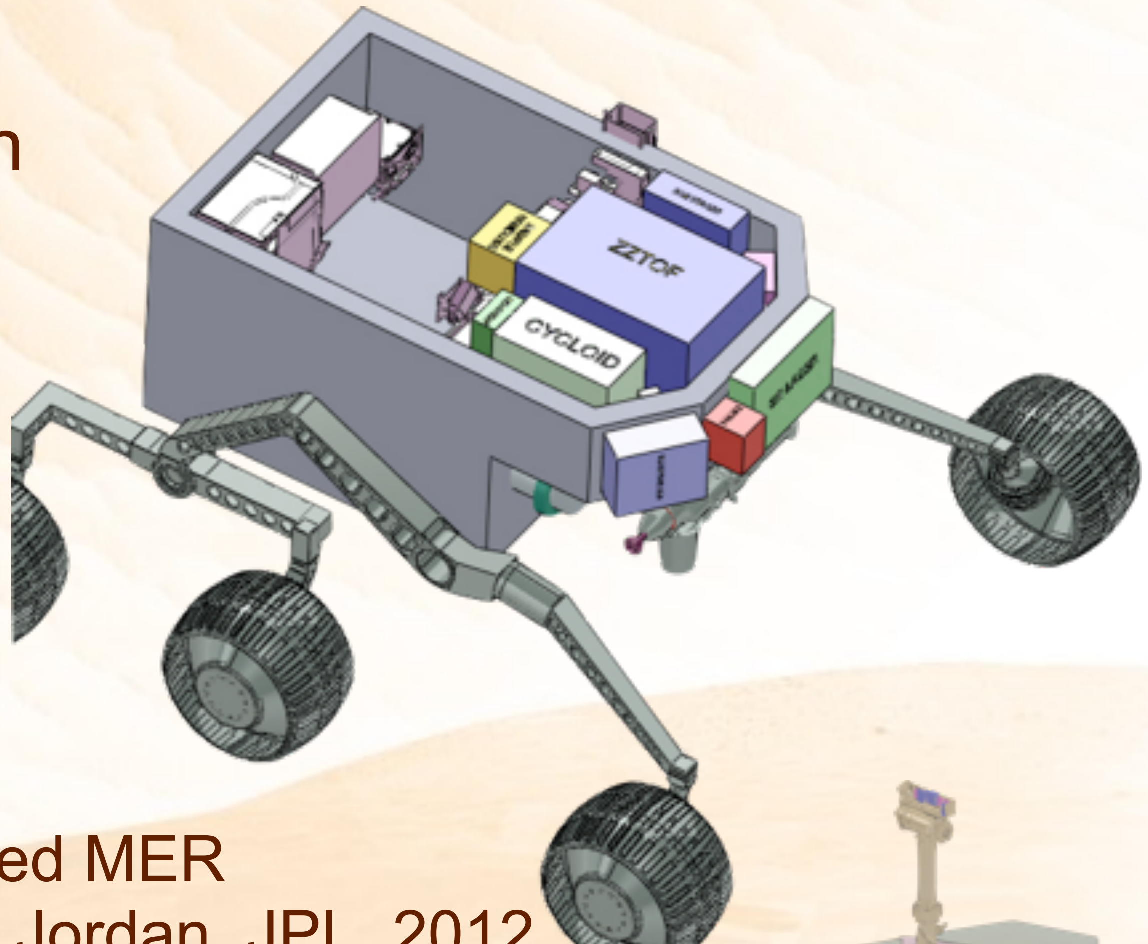
  1. Be responsive to the astrobiological and chronological science goals of MEPAG, Decadal Survey, E2E-iSAG, and MPPG

  2. Address the chemical & biochemical nature of the surface to fill “Strategic Knowledge Gaps” for human exploration of Mars

  3. Avoid the MSR *appearance* of lower priority MAX-C science coupled with initiation of large long term fiscal and political commitment

Mission Concept

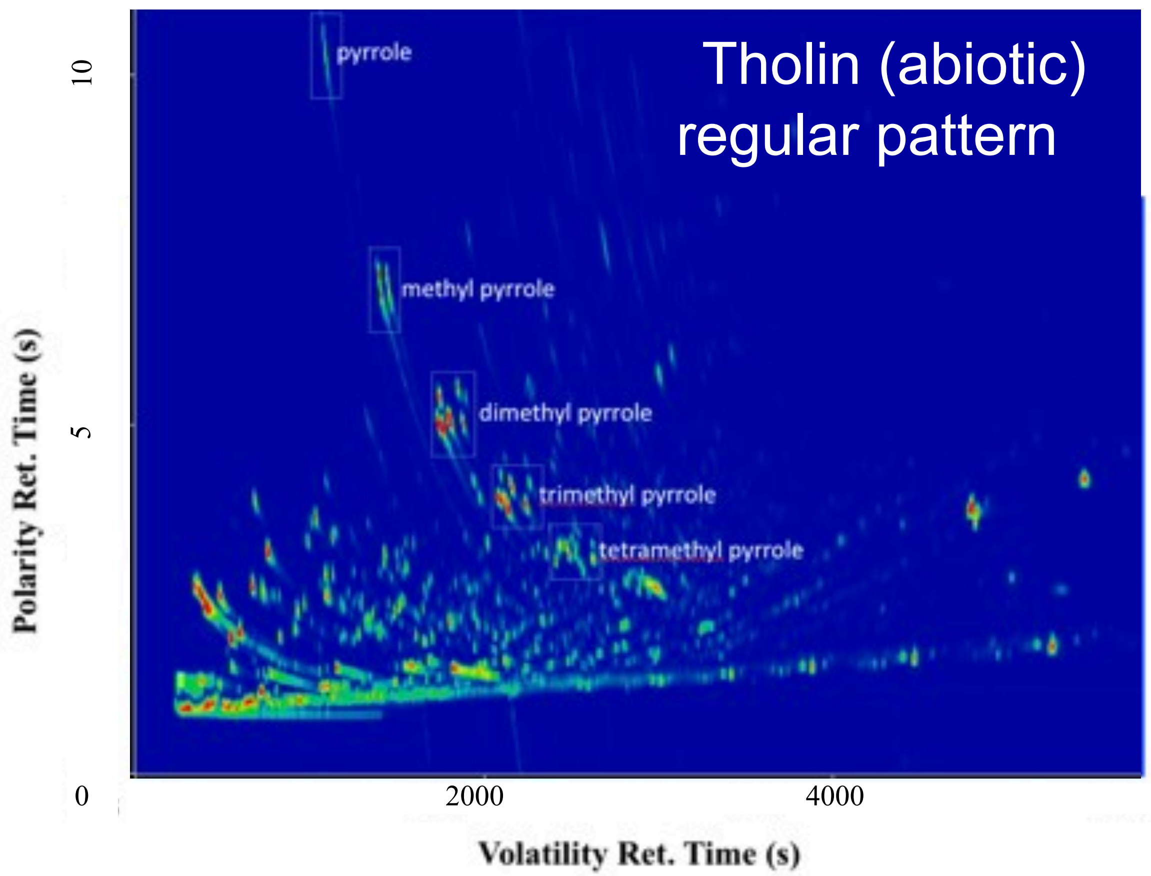
- To establish the validity of future MSR landing sites (triage):
  - Upscaled MER (JPL: 40+ kg, ~10 km ellipse, ~$650M)
  - Triple coincidence life detection/organic identification
    - Laser desorption/ablation (soft/hard ionization) & cryotrap
    - GCxGC enables:
      - Mass spectra of all compounds
      - Organic compound pattern recognition
    - Isotope ratios of all compounds
    - Chirality
  - LDRIMS: Rb-Sr geochronology
    - µRaman for simultaneous mineralogy
    - MS + LIBS = K-Ar geochronology
  - Imaging

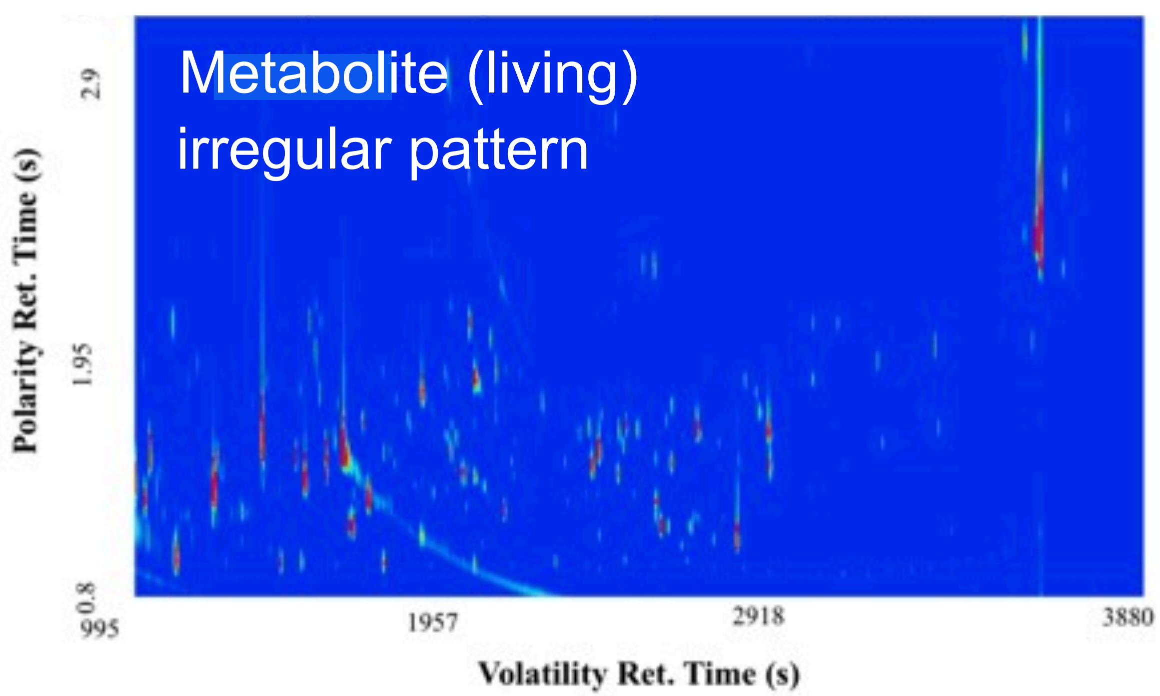


Updated MER
Cindy Kahn, Beth Jordan, JPL, 2012
(*c.f.* Ehlmann et al, 2012; Calvin et al, 2012)

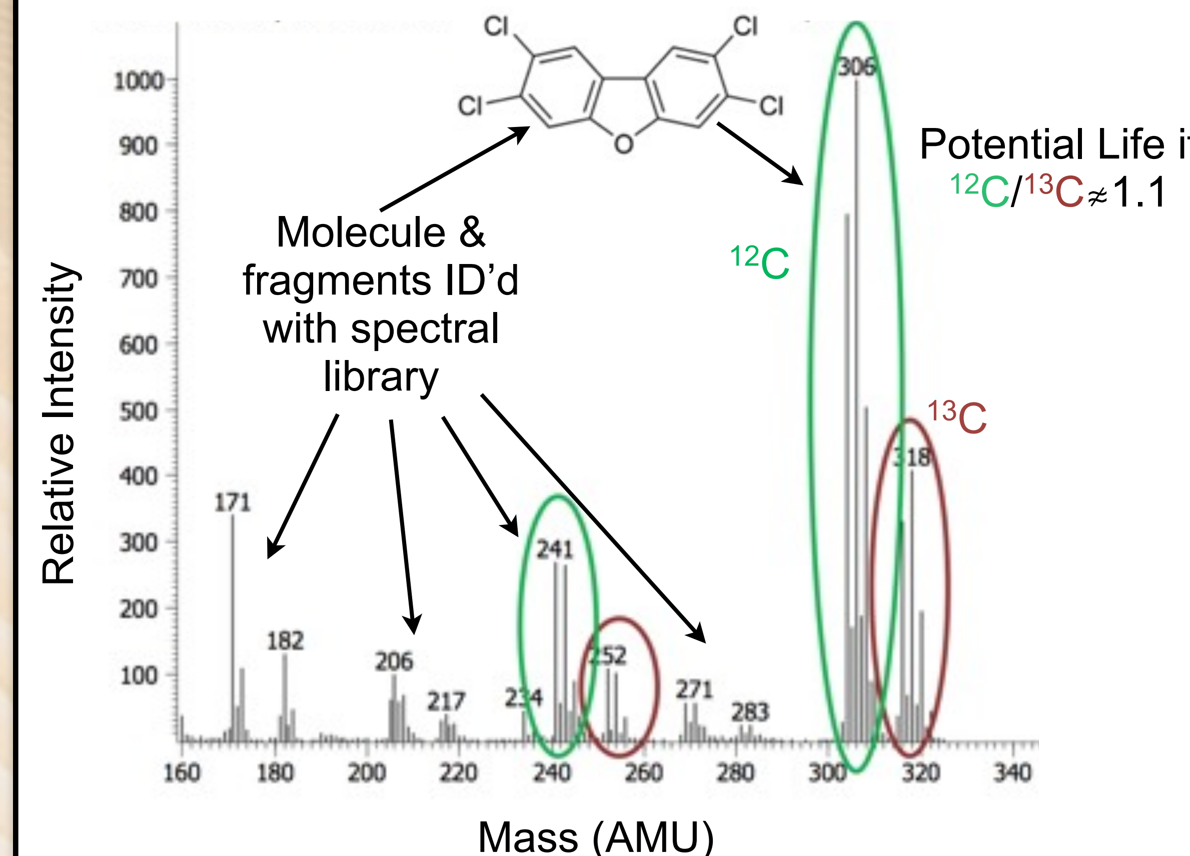
Pattern Recognition, Spectral Identification, Isotope Ratios, Chirality

Pattern Recognition

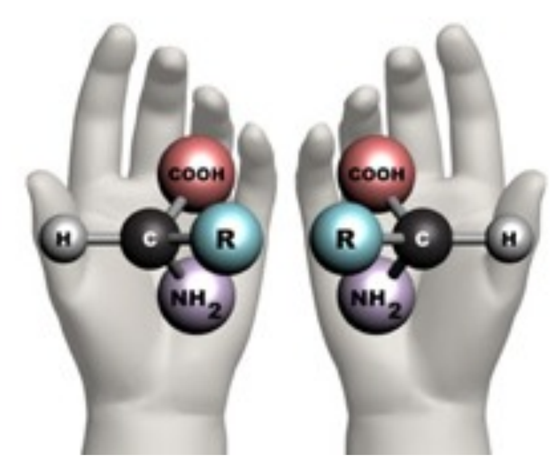




Spectral Identification and Isotope Ratios

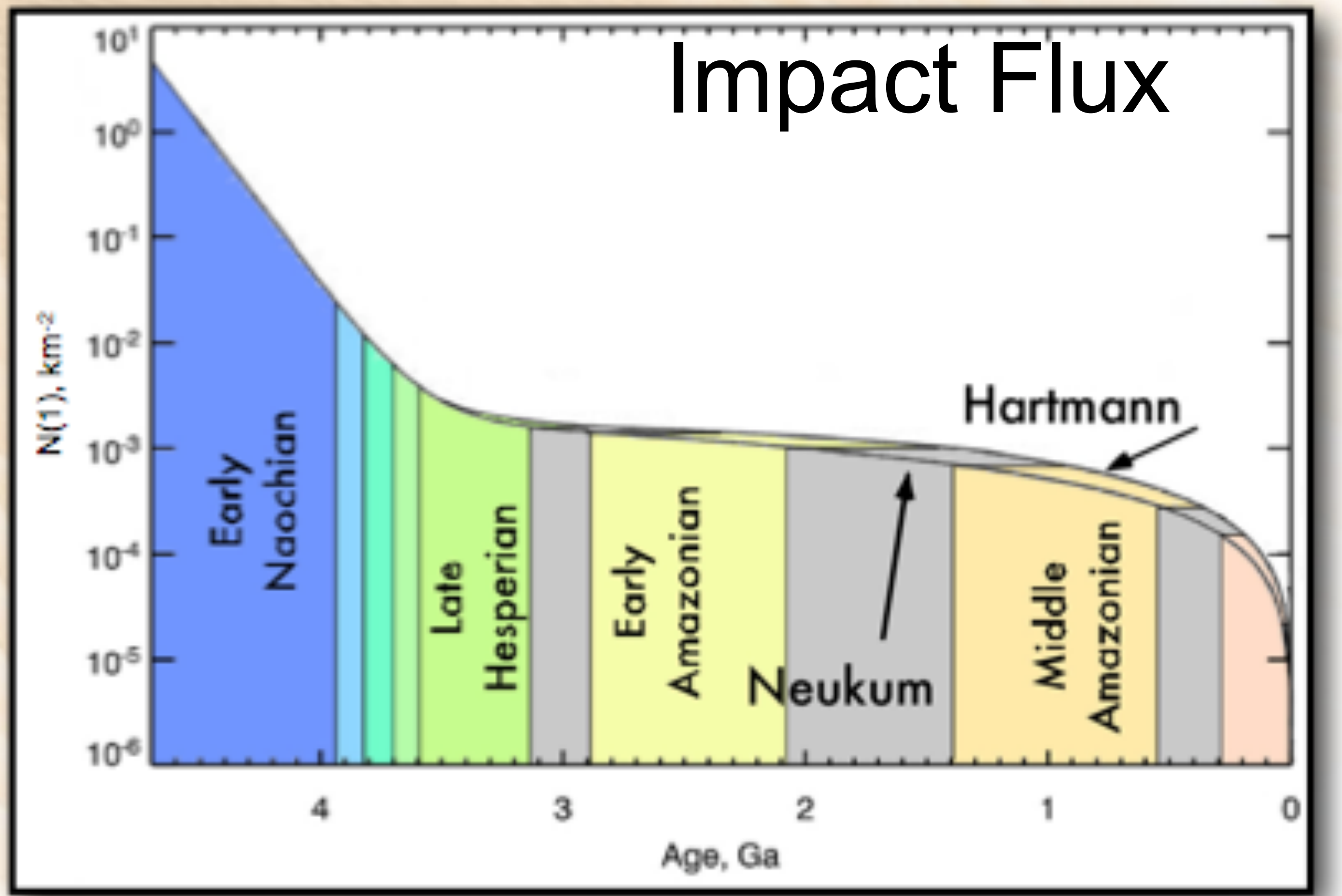


Chirality



Why geochronology for Mars?

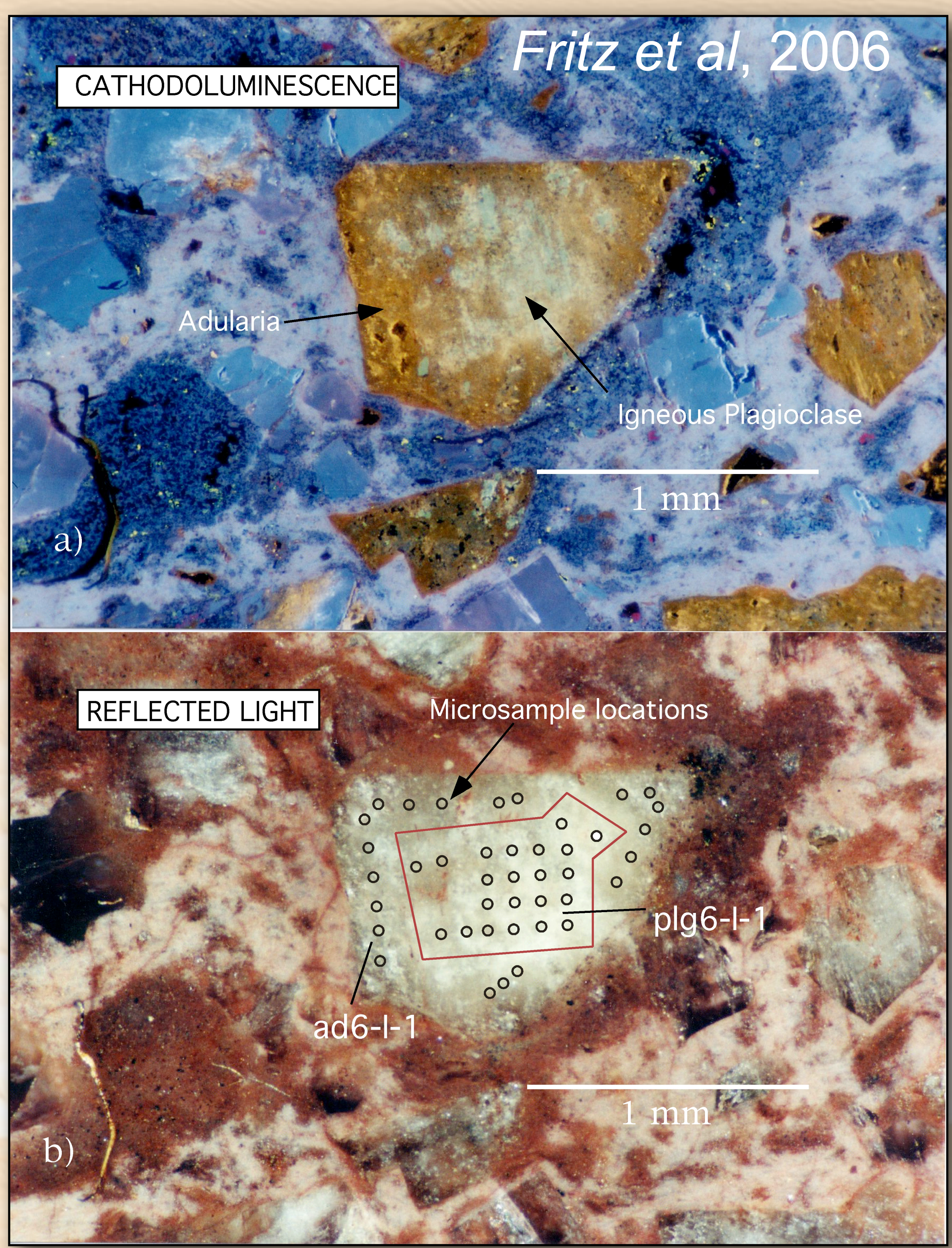
- Surface age estimated by crater counting, a function of impactor flux
  - Uncertainty in scaling flux from Moon to Mars
  - Range of up to ~ 700 Ma
- NRC DS supports "... focusing on ... in situ geochronology";
- MEPAG Goals III.A.3-10, call for "Constrain[ing] the absolute ages ... with both in situ and returned sample analysis...";



Modified from *Hartmann & Neukum*, 2001

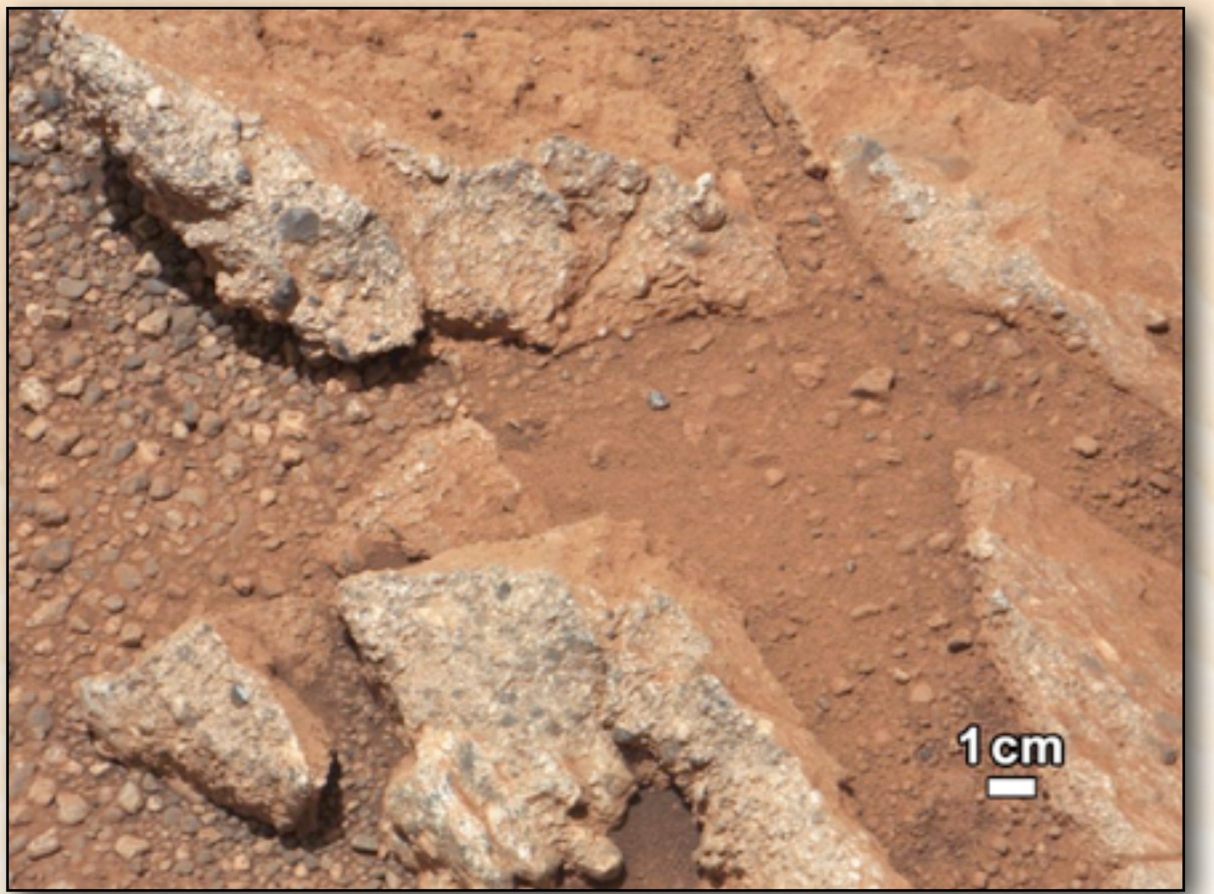
- NASA's integrated technology roadmap [Barney et al., 2010] calls for "Surface Chronology" [TA08-2] and "Age Dating [to] ±200 Myr on surface";

Dating the Water: Cementation



- Rb-Sr dating used to date primary formation and secondary alteration
- Lemitar Tuff, NM
  - Tuff: 28 Ma
  - Metasomatism & cementation 6 Ma
- Conglomerates?
- Hydrothermal sites ideal for identifying life?
- Evidence for aqueous alteration abundant on Mars
  - Hydrothermal brines
  - Carbonate cementation & Induration
  - Global chlorides

Dating the Water: Cementation



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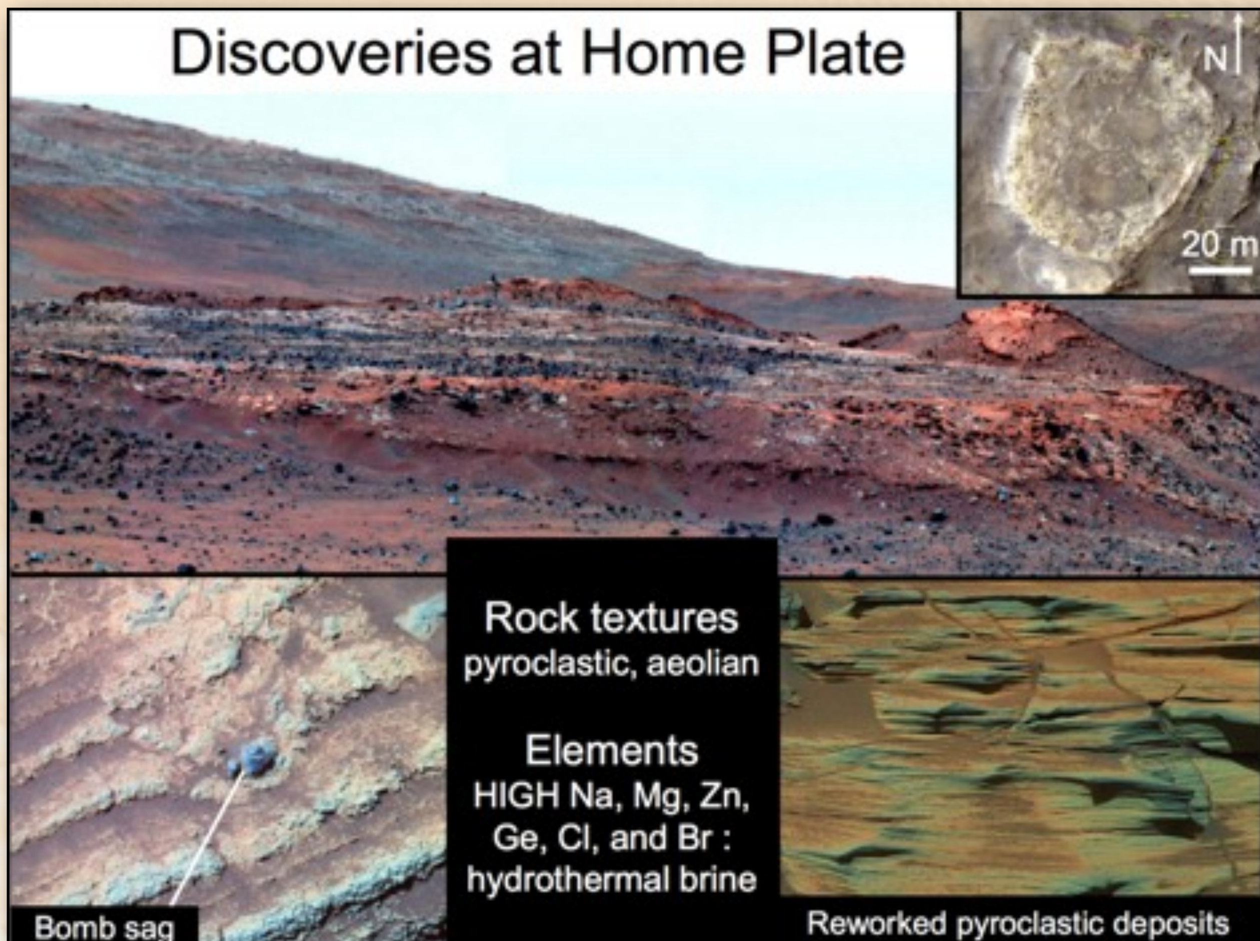

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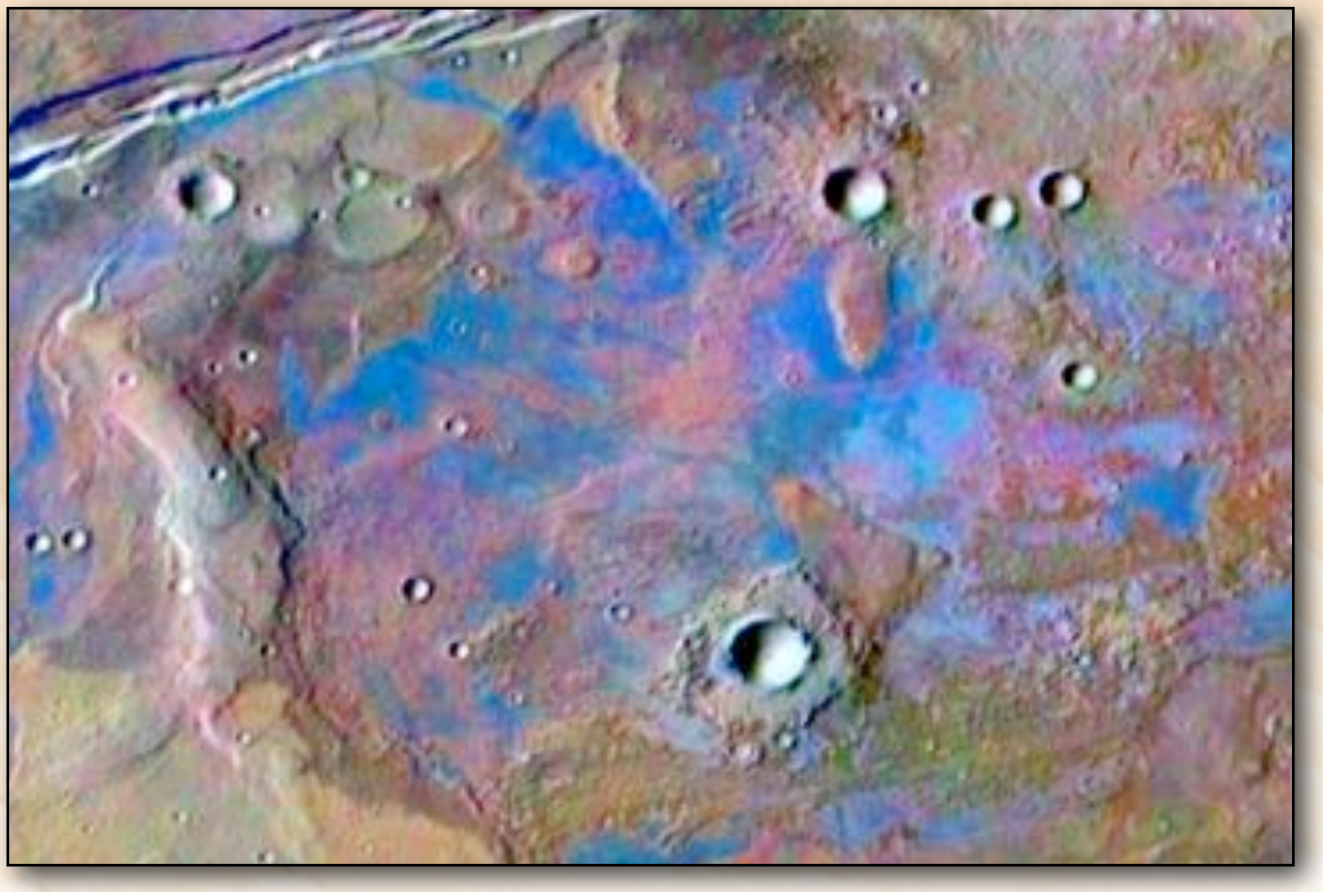

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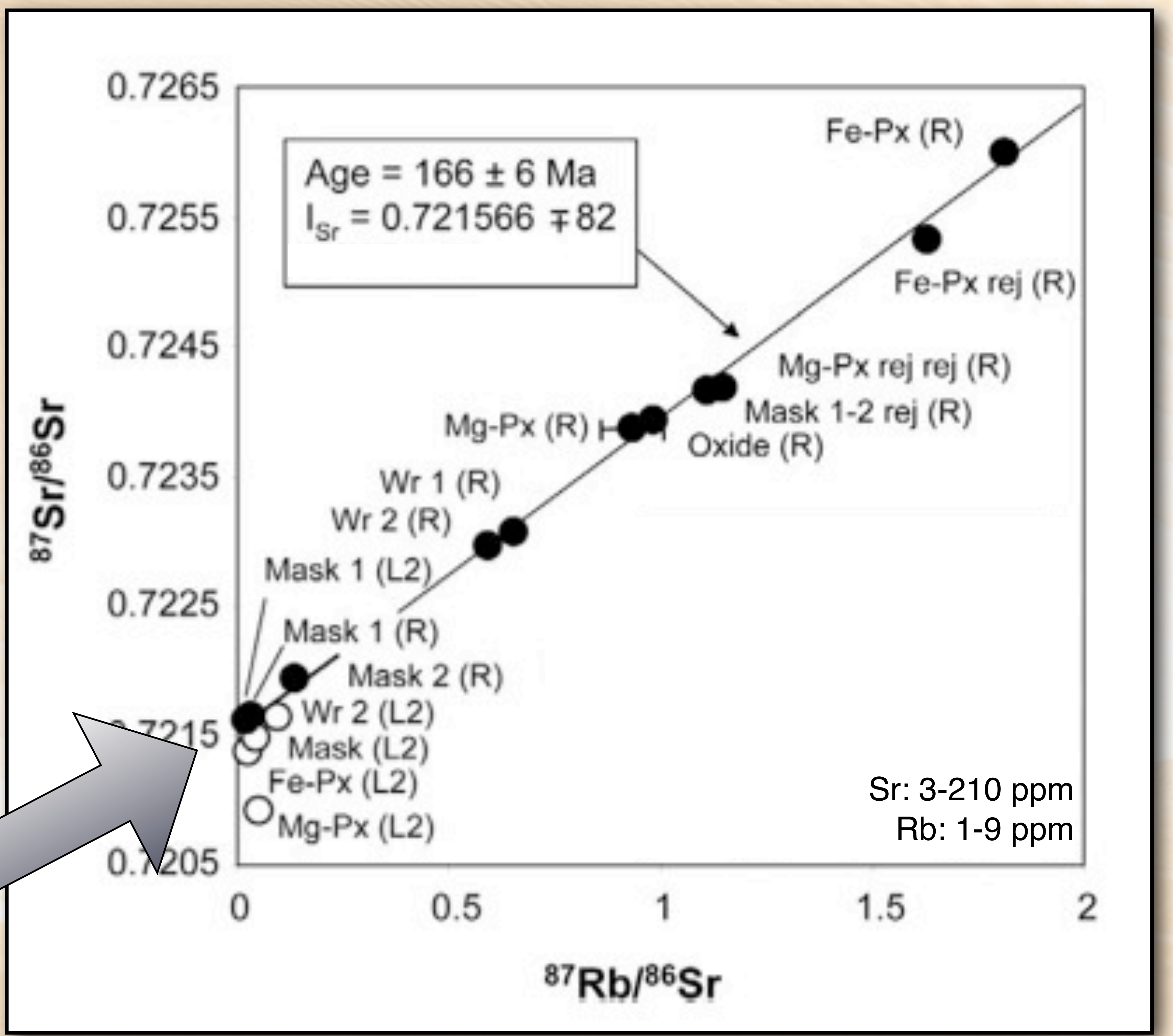
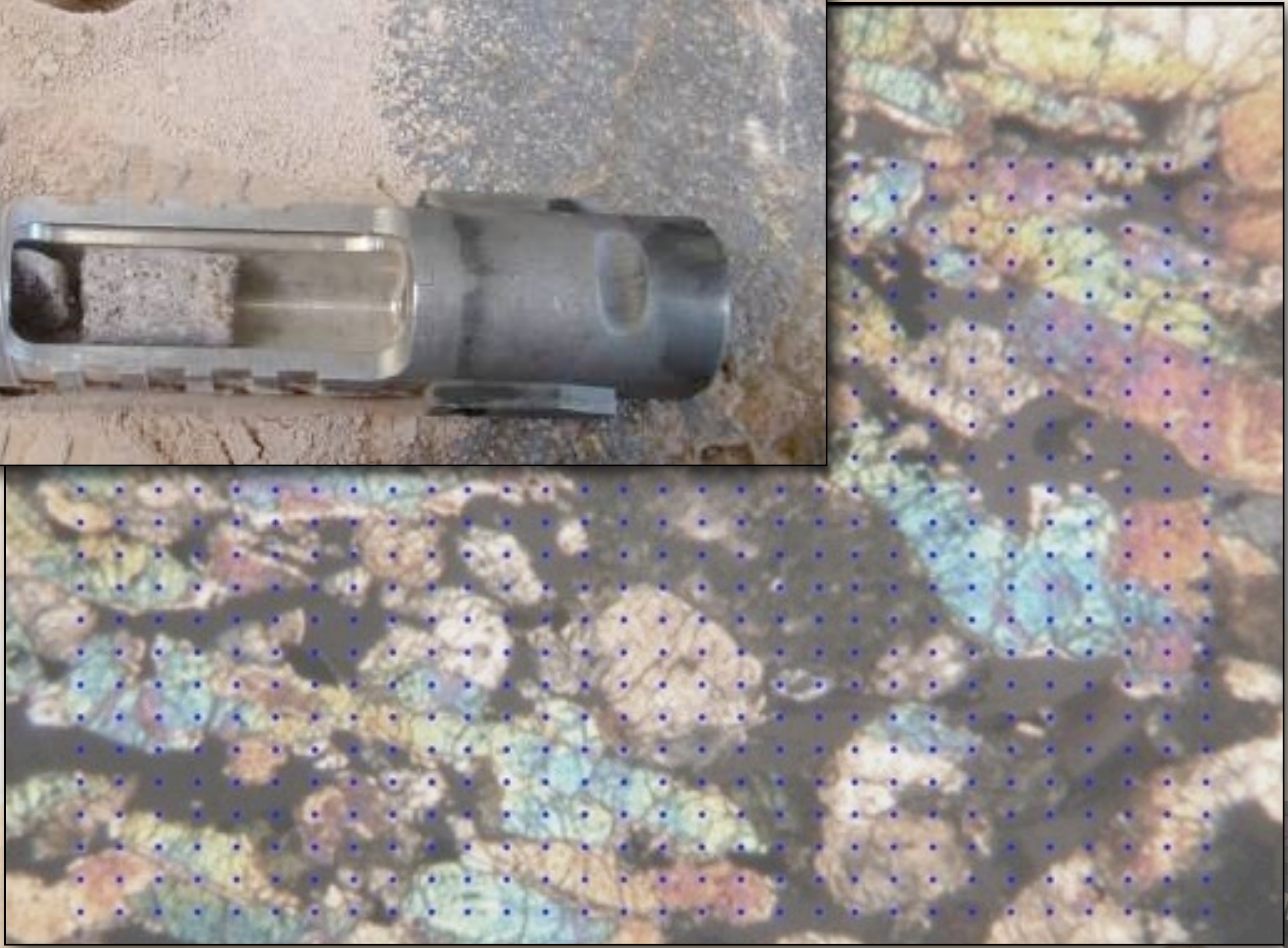
Mars: Zagami Rb/Sr Isochron



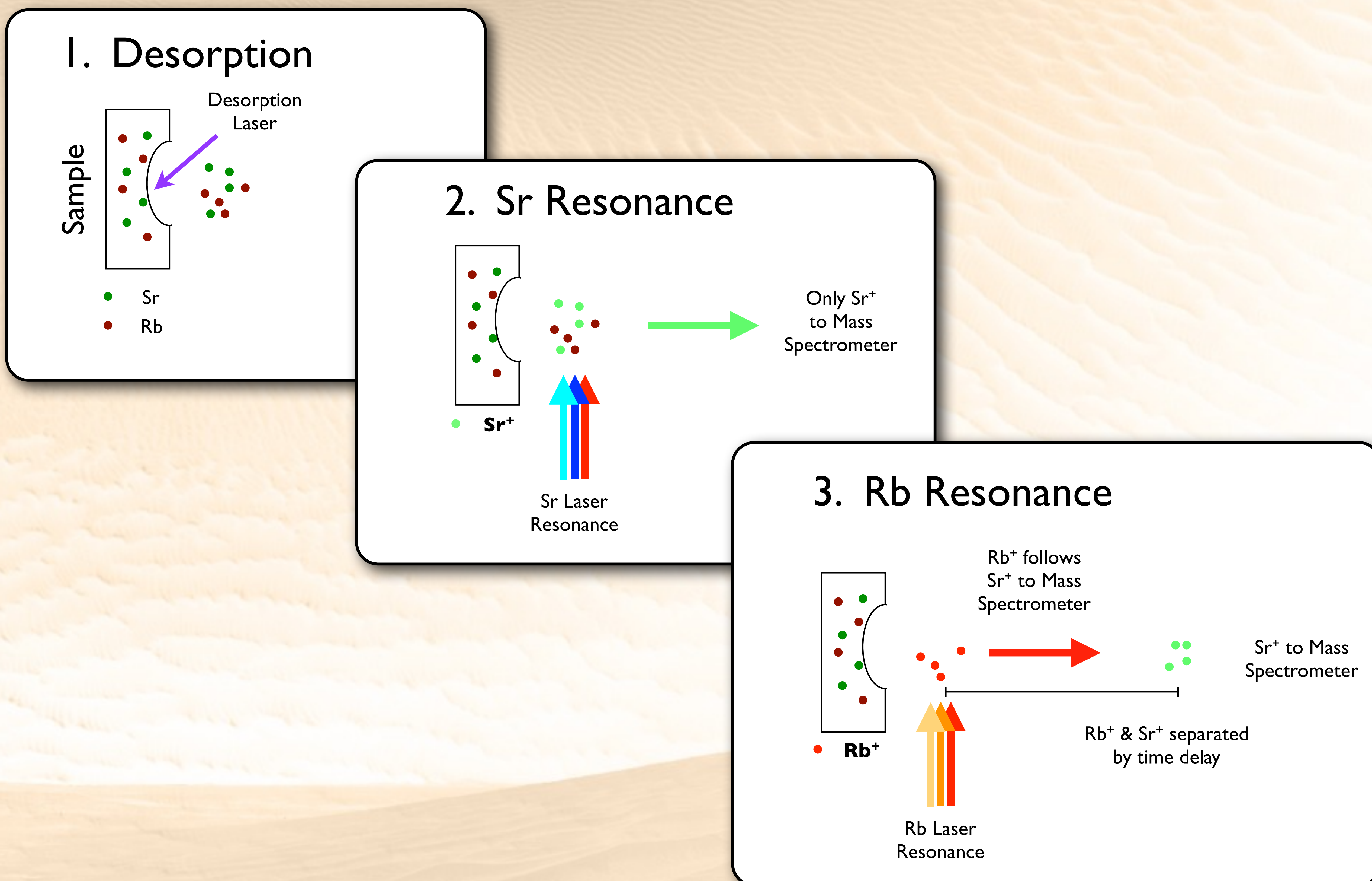
Intercept: Initial $^{87}Sr/^{86}Sr$ ⇒ melt evolution

Adapted from Borg et al, 2005

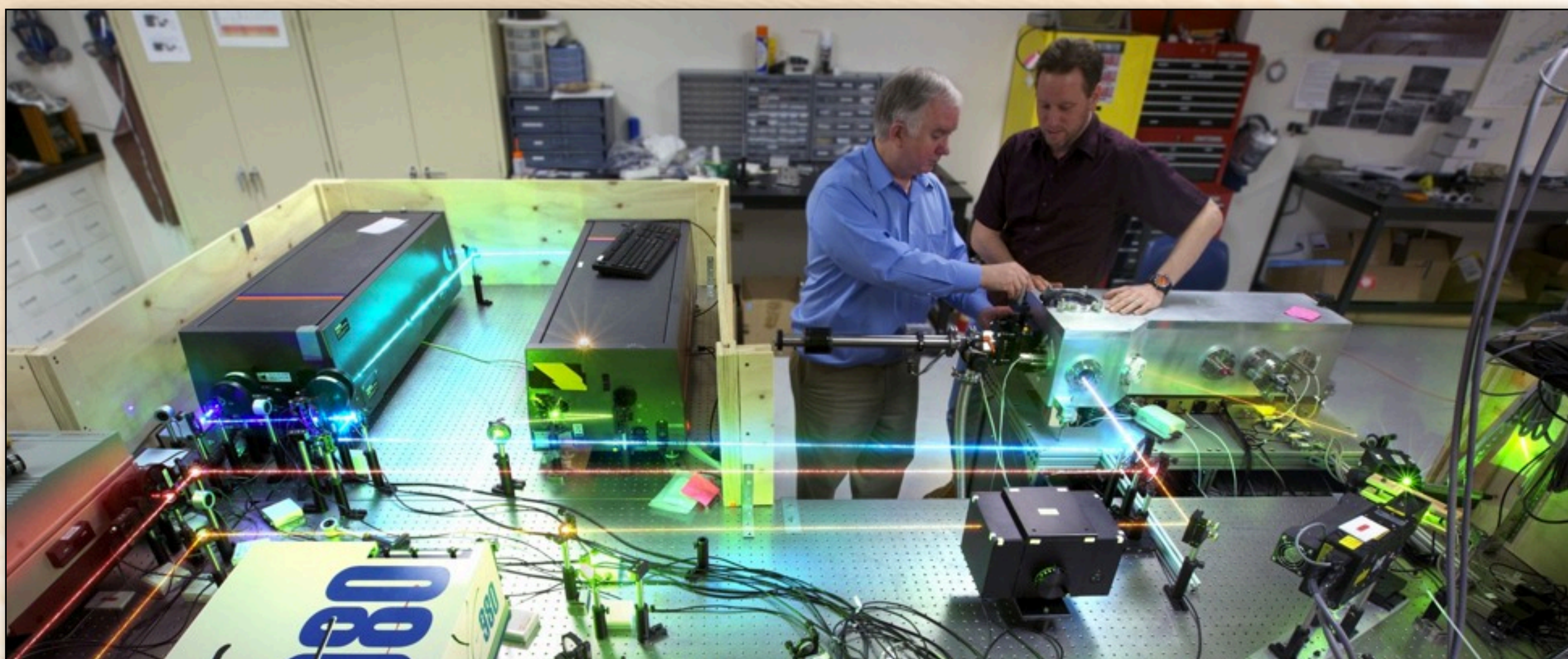
Core & Grid Pattern



LDRIMS: How It Works

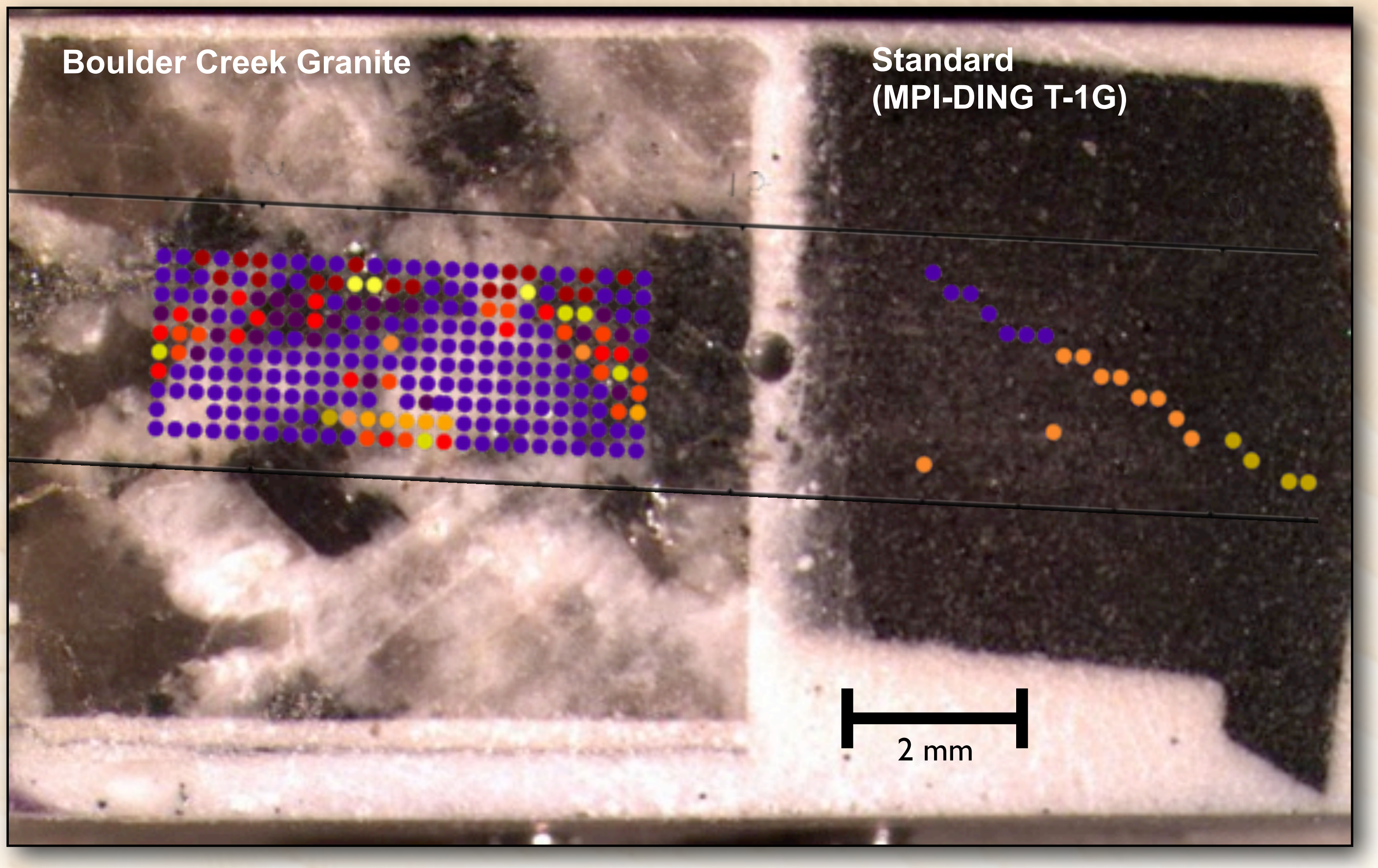


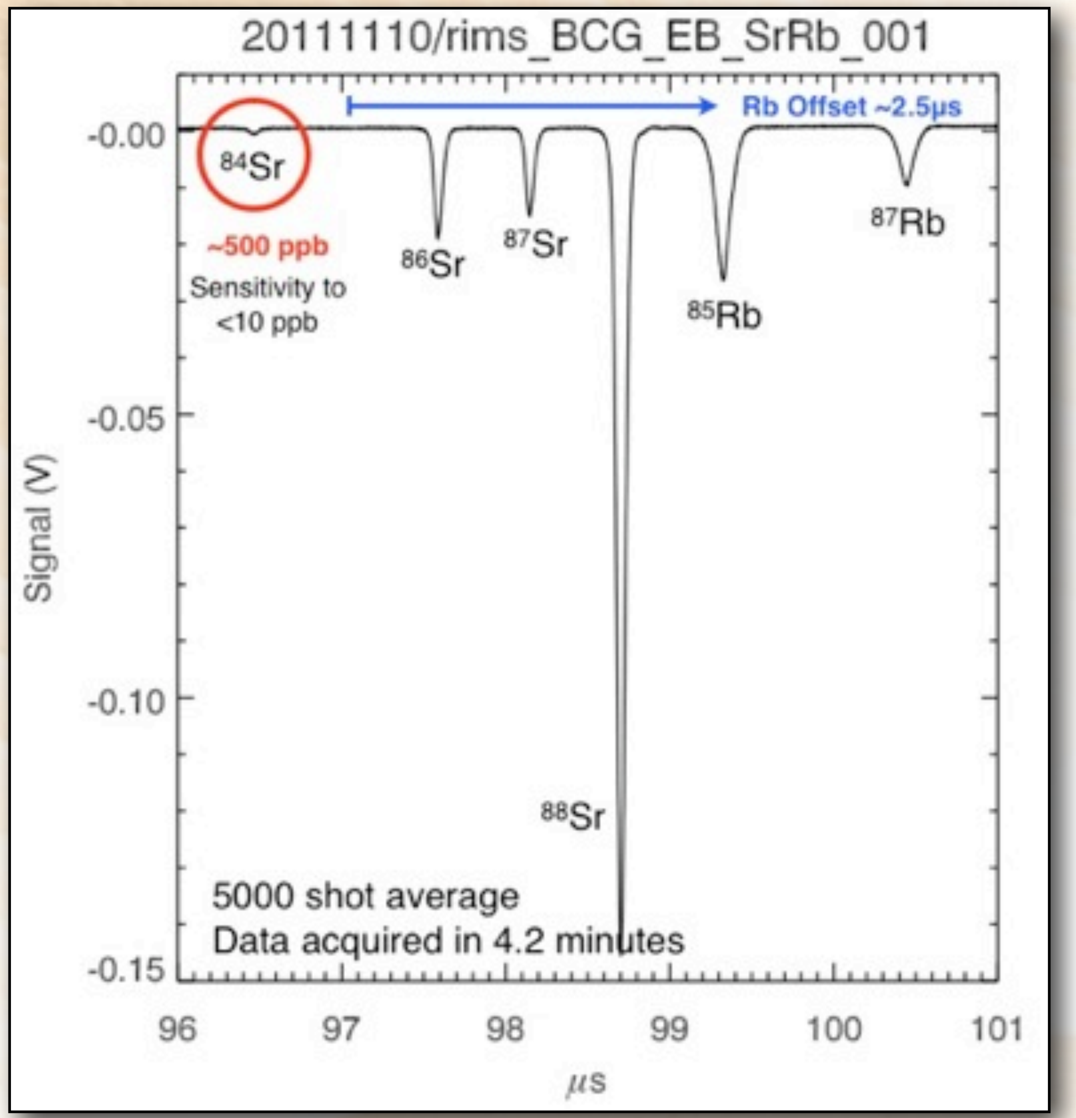
Bench-top Prototype LDRIMS



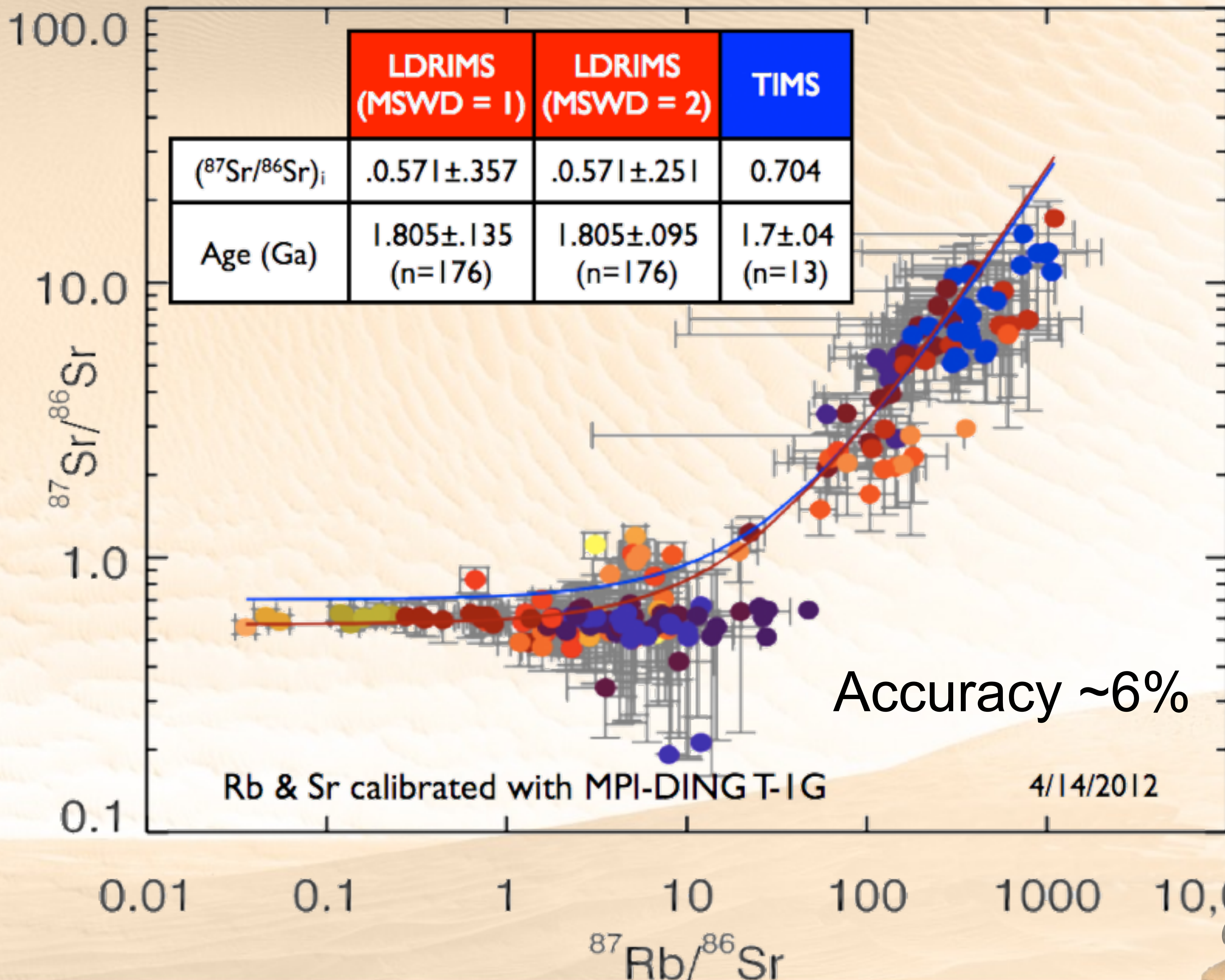
This is a photomontage: always respect laser safety

LDRIMS Example





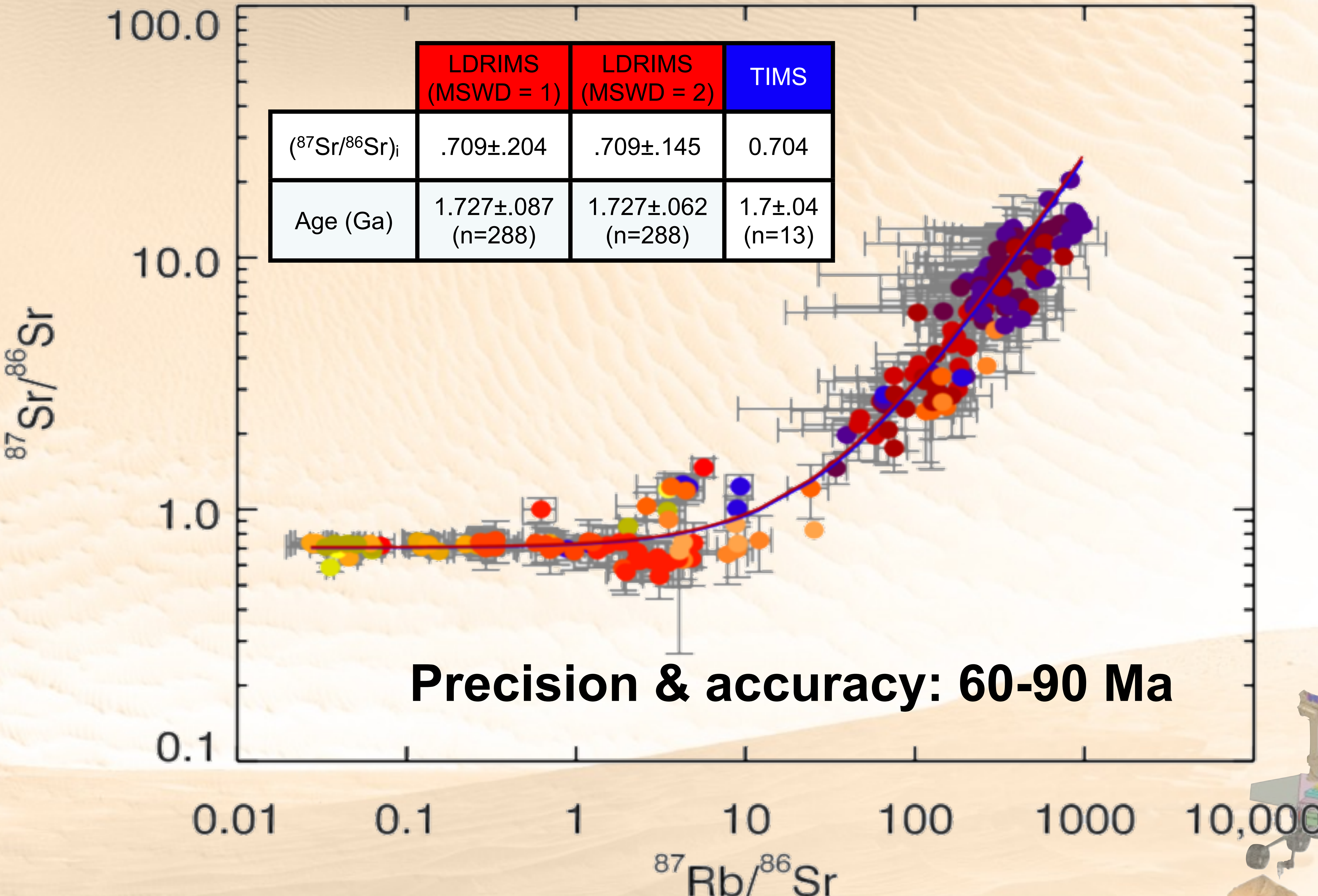
Calibrated Isochron



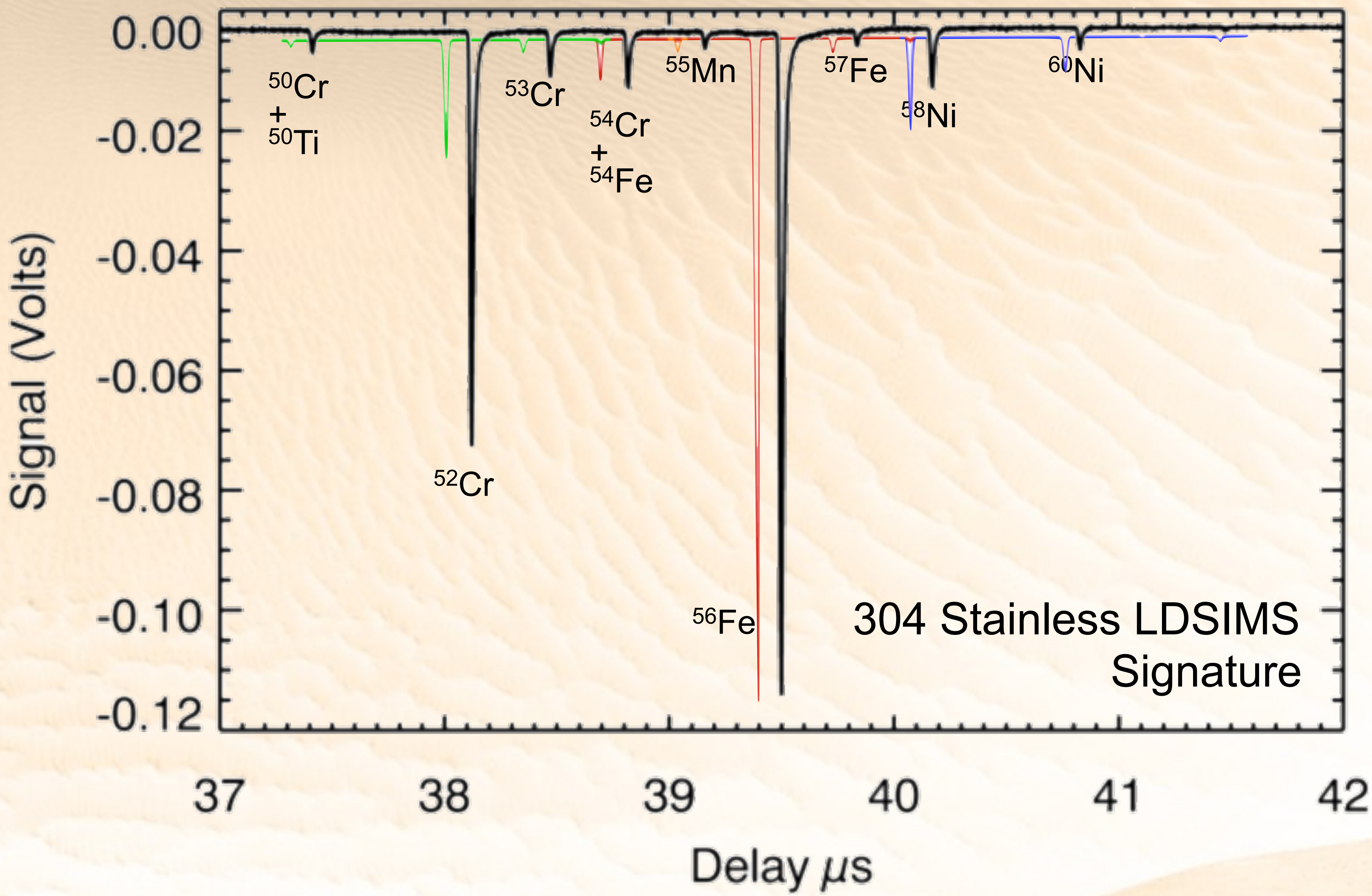
	LDRIMS (MSWD = 1)	LDRIMS (MSWD = 2)	TIMS
$(^{87}Sr/^{86}Sr)_i$	.0.571±.357	.0.571±.251	0.704
Age (Ga)	1.805±.135 (n=176)	1.805±.095 (n=176)	1.7±.04 (n=13)

Calibrated Replicate Isochron

	LDRIMS (MSWD = 1)	LDRIMS (MSWD = 2)	TIMS
$(^{87}Sr/^{86}Sr)_i$	.709±.204	.709±.145	0.704
Age (Ga)	1.727±.087 (n=288)	1.727±.062 (n=288)	1.7±.04 (n=13)

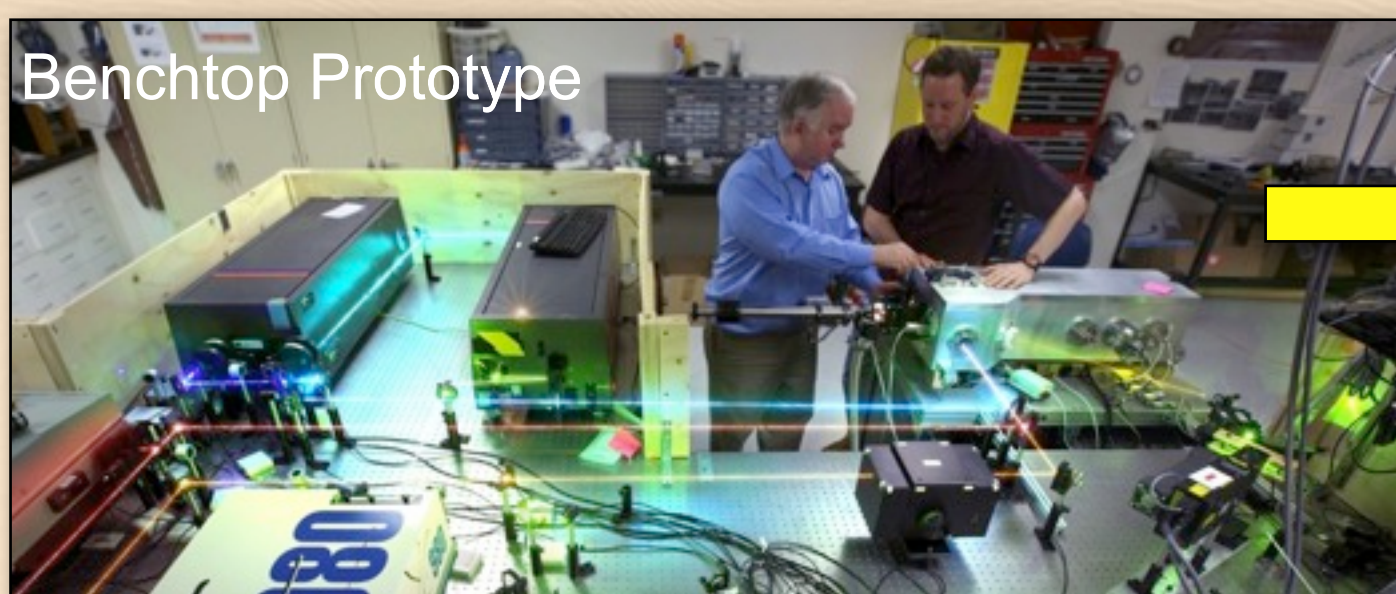


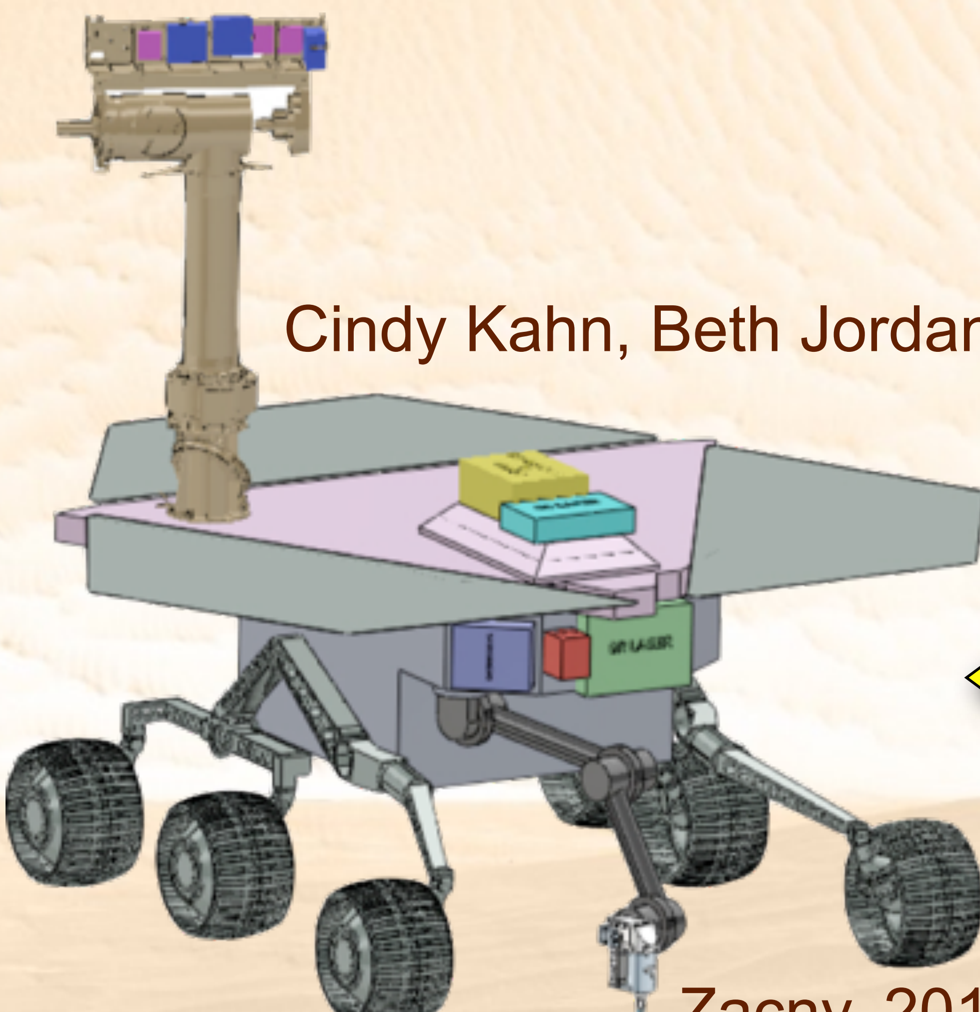
Geochemistry



- The LDRIMS system is also capable of Laser Desorption Secondary Ionization Mass Spectrometry (L2MS) without modification
- Enables geochemistry accurate to ~5-10%

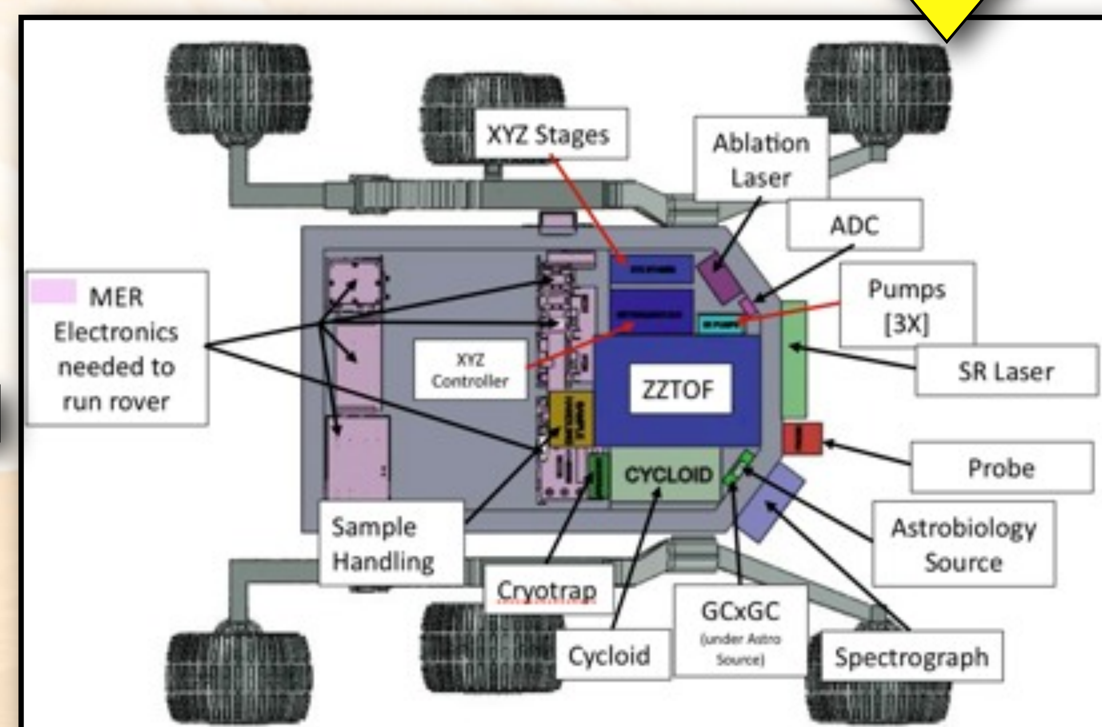
Portable LDRIMS & Preliminary MER-Design



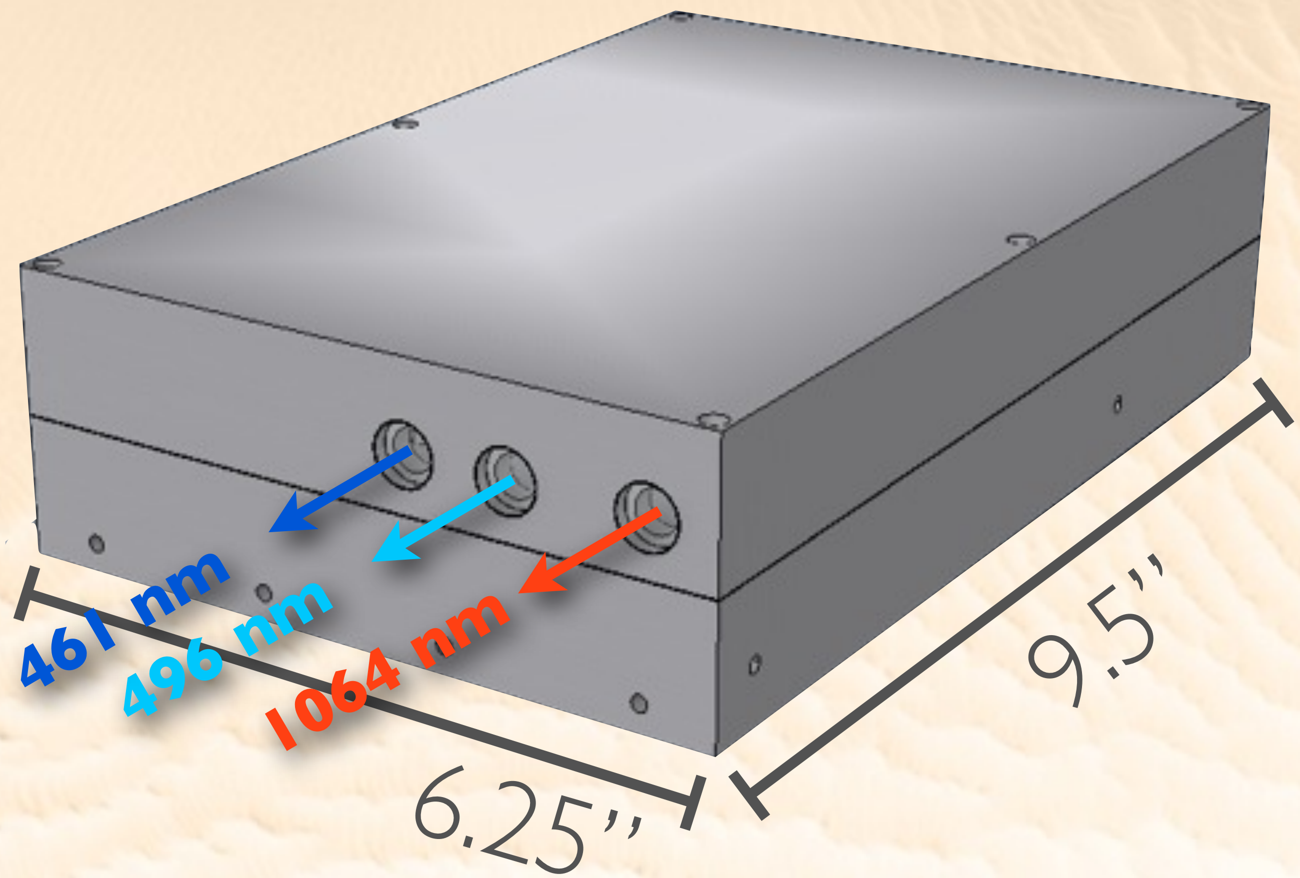


Cindy Kahn, Beth Jordan, JPL

Zacny, 2012



LDRIMS 2 LASER subsystem



Current LDRIMS with HBR/MDA Rover & Arm

LDRIMS 2 in *Nature*

NEWS FEATURE

THE TIME MACHINE

Dating features on the Moon and Mars is guesswork. Scott Anderson is building a tool to change that.

BY ERIC HAND

The bits of rock on Scott Anderson's shelf are not much to look at, but they have stories to tell. In a plastic case is a greenish-grey rock, a 4.5-billion-year-old piece of the asteroid Vesta. Next to it rests a dark sliver of 2.8-billion-year-old lava from the Moon. Anderson, a planetary scientist at the Southwest Research Institute in Boulder, Colorado, picks up his favourite, a 1-gram slice of rock that cost him US$800. The flake came from Zagami, an 18-kilogram meteorite named after the Nigerian village where it was found in 1962. It is one of the rarest and most sought-after types of meteorite — a piece of Mars that was blasted into space by an asteroid impact and eventually landed on Earth. "Knowing what it is makes me excited to see it every time," Anderson says.

What Anderson wants from these far-flung fragments of the Solar System is elementary: their ages. Coaxing out that information is far more difficult. Zigzagging across his laboratory is a web of laser beams that feed into a mass spectrometer — all part of a geochronometer that Anderson is building. Like other rock-dating systems, this one computes an age from the radioactive decay of certain isotopes in a sample. What sets Anderson's system apart is his goal to shrink the whole operation down to something that would fit on a desktop. Then, rather than waiting for planetary fragments to fall to Earth, he wants to send his device to the planets.

Over the past few decades, planetary scientists have mapped the Solar System in ever more staggering detail. Cameras orbiting the Moon and Mars can zoom in on objects as small as dinner plates, and radars can penetrate several metres below the surface. But when it comes to the fourth dimension — time — they are as blind as ever. Scientists have hard dates for only nine places in the Solar System, all on the Moon: six Apollo sites and three Soviet Luna sites, from which samples were returned robotically. When did water flow on Mars? When did the Moon's volcanoes last erupt? Without dates, planetary scientists can only make educated guesses about some of their most pressing questions.

A portable, *in situ* chronometer such as Anderson's could revolutionize how researchers study the Moon, Mars or other rocky bodies. The costs of big planetary missions are skyrocketing; the $2.5-billion Mars Science Laboratory that is scheduled to land on 6 August is one of the most expensive Mars missions ever. But Anderson's tool could reduce future costs, in particular by avoiding the need for budget-busting missions to retrieve samples from other planets and haul them back to Earth. And the device could even find a wide audience on Earth, among geologists who could use it to map the ages of rocks in the field, rather than delivering samples to a lab and waiting months for the results.

MATTER OF SCALE

But first, Anderson has to transform the finicky set-up that sprawls across his lab into one that could fly in space. Other groups are trying to develop portable geochronometers, but Anderson's design has some advantages, and he is closer to completing a working prototype. At present, the half-built apparatus sits in the corner of his office: 160 kilograms of gleaming steel and aluminium, roughly the size of a two-drawer filing cabinet. He hopes to finish it later this year, and then he will bolt it into the back of a van and take it on a road trip. "We've been talking about how we could drive this to NASA headquarters and test this in the parking lot," says Anderson. At 44 years old, he is tall and boyishly earnest, but savvy enough to understand good public relations. He wants to persuade NASA officials to pay to build an ultra-lightweight geochronometer and then send it on a rover to the Moon or Mars.

Anderson will have to show not only that his chronometer is fast and light, but also that his dates make sense. Radiometric dates are some of the trickiest, most delicate and most disputed measurements on Earth. Anderson wants to transform what has been a laborious process of chemical extraction and analysis into a laser-based system, automate it and shrink it into a robot small and reliable enough to send

➲ NATURE.COM
For more on Mars and the Curiosity mission, see:
go.nature.com/fknipi

PHOTO BY MATT NAGER

Scott Anderson plans to finish the prototype for his portable geochronometer later this year.

Friday, October 12, 12

Payload Elements Consistent with MER

Payload Component	TRL	Cost (M $)	Mass (kg)	Power (W)	Total Power (W-hrs)/ Date	Total Power (W-hrs)/ Bioassay	Volume (cm^3)
Shared ZZTOF & Electronics	3	22	10.0	5	43.8	3	12000
3 Pumps	9	2	1	3	25.0	48	92
Sample Handling	3	3	2	1	-	1	640
XYZ stages	4	1	0.3	-	-	-	1033
XYZ Controller	4	1	0.5	5	0.4	-	1080
ADC	5	4	1	4	50	2	36
Astrobiology Source	4	2	0.3	0.5	-	0.25	7
Cryotrap (Rycor)	6	2	2.5	6	-	36	190
GCxGC	4	4	2.5	5	-	30	70
Cycloid	5	10	2.0	1.5	-	9	3000
Dating Source	-	4	0.3	0.5	6.25	-	-
Ablation Laser	5	3	1	3	38	-	306
Sr Laser	4	4	2.5	6	75	-	1418
Rb Laser	4	3	2.1	5	63	-	1170
Fiber harnesses	-	-	0.5	-	-	-	-
uRaman & electronics	5	8	2.3	5	4	-	2400
Probe	5		0.2	-	-	-	299
Spectrograph	5		-	-	-	-	950
Arm (IDD)	9	10	2.5	-	-	-	-
Drill/Coring/Abrading/scoop	5		1.5	45	8	8	168
Cameras x3	9	5	0.795	2	12	12	94
Camera electronics x3	9						472
Totals		88	35.7		324	148	24952

Payload Elements Consistent with MER

Payload Component	TRL	Cost (M$)	Mass (kg)	Power (W)	Total Power (W-hrs)/ Date	Volume (cm^3)
RTOF & Electronics	6-9	22	10.0	5	43.8	12000
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Sample Handling	3	3	2	1	-	640
XYZ stages	4	1	0.3	-	-	1033
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ADC	5	4	1	4	50	36
Dating Source	-	4	0.3	0.5	6.25	-
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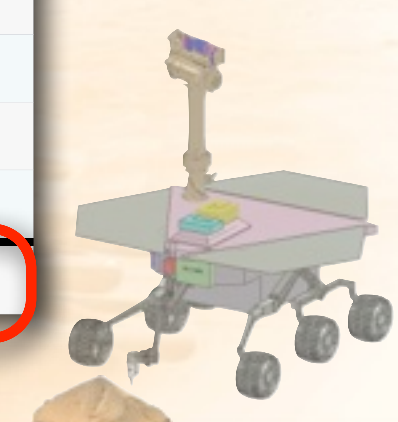
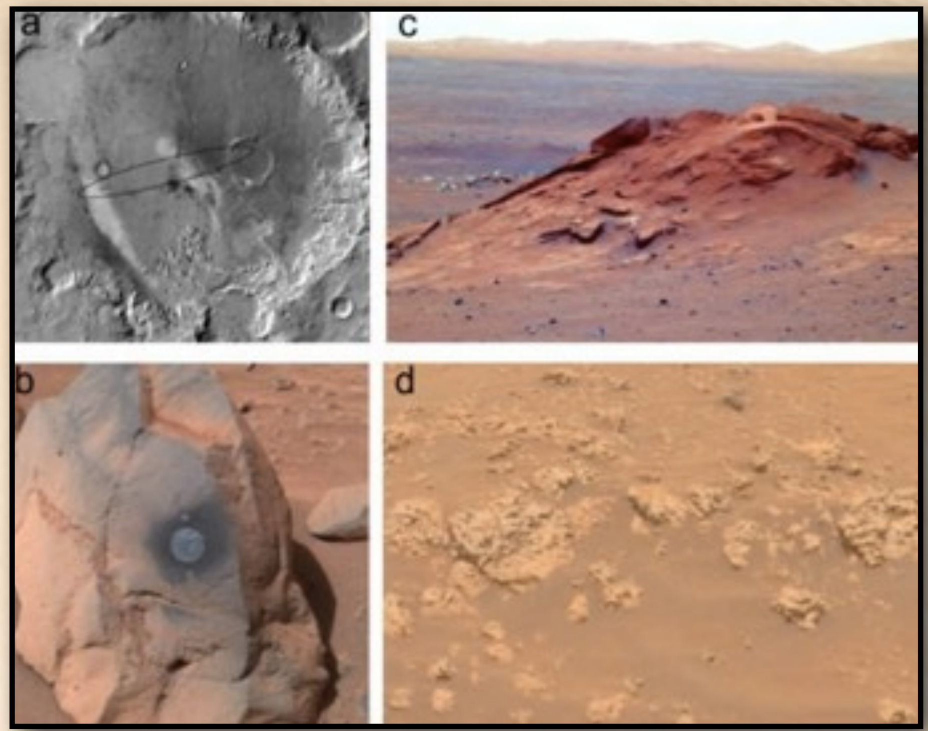
Drill/Coring/Abrading/scoop	5		1.5	45	8	168
Cameras x3	9	5	0.795	2	12	94
Camera electronics x3	9					472
Totals		70	28.5		324	22157

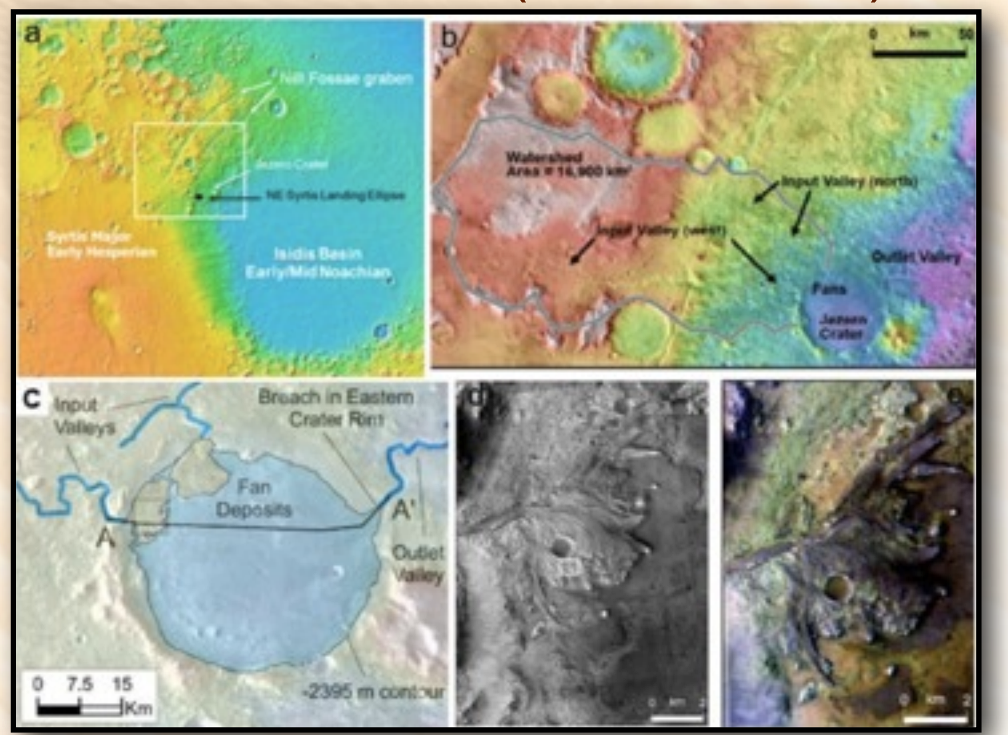


Concept Consistent with E2E-iSAG Reference Landing Sites

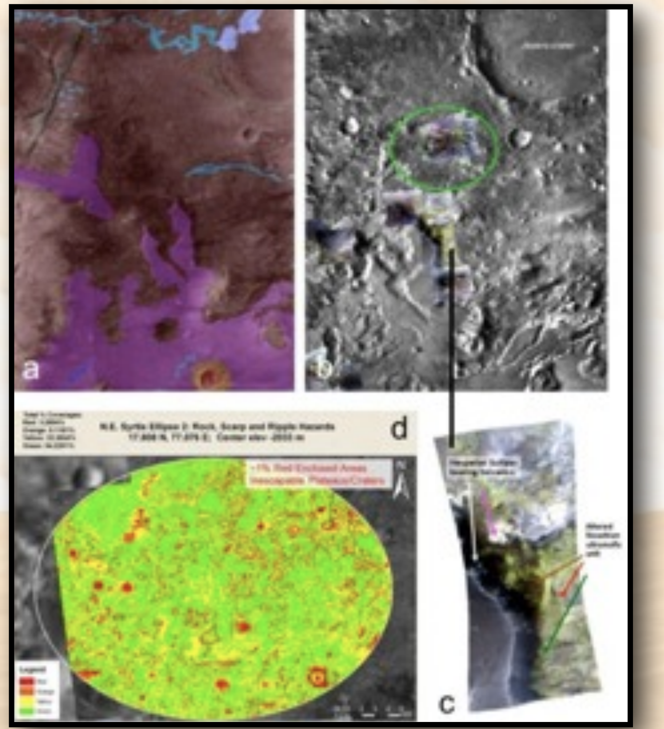
Gusev (14.3°S, -2 km)



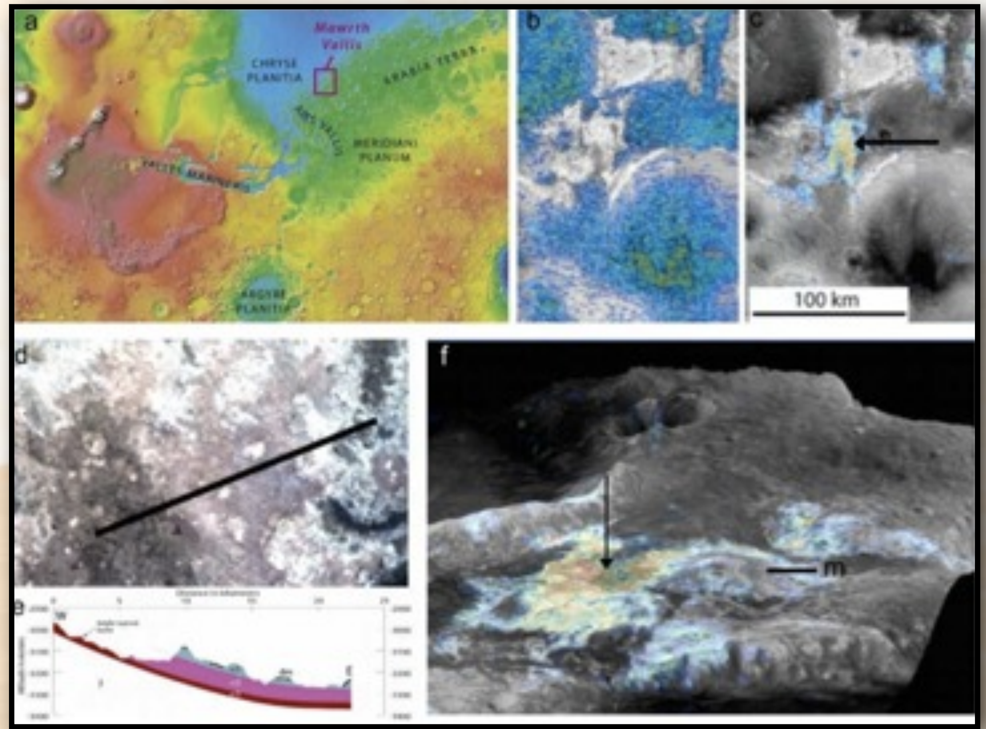
Jezero Crater (18°N, -3 km)



NE Syrtis (16°N, -2 km)



Mawrth Vallis (25°N, -3 km)



Responsiveness: Hitting the Sweet Spot

Constraints	Solution
1. Science: MEPAG, DS, E2E-iSAG	MP: III.A.3-10, III.B.1-3, I.B.2 & DS: Habitability/life/organics/dating E2E: Priorities 1-3, 5, and 8
2. Humans: SKG	B.2 (organic biohazards), B.7 (chemistry/ISRU)
3. More science now; less commitment	High order, DS relevant science (astrobio & dating); open to a cache if room
4. Cost	$750M-$800M + $400M reserve

- Dating & organics important for MSR triage
- Apollo experience suggests we will want more samples (or dates) after sample return
- Could replace some MSR science if MSR too expensive