CheMin-V: A Definitive Mineralogy Instrument for the Venera-D Mission

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X-ray diffraction: the benchmark technique for definitive identification and quantification of minerals



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Conventional lab XRD: Large, power hungry machine, with require precise movements for measurements.

XRD miniaturization for spaceflight



Transmission geometry eliminates need for moving parts.

Piezo actuated sample cell produces random orientation in sample powders during analysis.

Miniaturized XRD realized: On Mars and Earth



MSL Mission



MSL's main goal: to determine if ancient Mars environments were habitable. 2D X-ray Diffraction patterns from CheMin at Yellowknife Bay.
Lake mudstones contain up to 30 wt.% clay minerals.

Habitable lakes

Stratigraphic changes in types of Fe-oxide minerals



Aqueous alteration



Value of Mineralogy (beyond bulk composition)

- Silica (e.g., Buckskin sample)
 - Tridymite
 - Cristobalite
 - Opal-A
- Iron oxides
 - Magnetite (Fe₃O₄)
 - Maghemite (Fe₂O₃)
 - Hematite (Fe₂O₃)
- Iron sulfides
 - Pyrite (FeS₂)
 - Troilite (Fe_{1-x}S)





Ground-truthing orbital data



CheMin Operation on Mars



- 15 pairs of cells 3 standards 27 reusable cells.
- Sample analysis times typically ~20 to 30 hours.
- But published results with analysis times as short as 2 hours (Morris et al., 2017 – PNAS).
- Detection limits: 1 wt.% for crystalline phases 5 wt. % for poorly crystalline phases (clay minerals).

Not practical for a Venus lander – with a lifetime of hours.

Improvements



Miniaturized X-ray tube is more powerful. 4 W in CheMin, 10 W in Terra, – 30 W may be possible.

Elliptical beam and elongate CCD utilize more of the X-ray beam for diffraction.

How quickly can a sample be effectively analyzed?

Quantitative abundances of crystalline components >5 wt.% in 15 minutes.

Phase	Terra 15 minutes	8 hrs conventional XRD
Andesine	35 wt.%	28 wt.%
Augite	15 wt.%	20 wt.%
Pigeonite	11 wt.%	13 wt.%
Forsterite	7 wt. %	8 wt.%
Ilmenite	ND	1.5 wt.%
Hematite	ND	0.4 wt.%
Magnetite	ND	1.1 wt.%
Cristobalite	4 wt.%	3 wt.%



CheMin-V



Geometry of the CheMin-V diffraction experiment

- Two samples are analyzed at the same time on a single CCD detector.
- SDD detectors (yellow) record the XRF spectrum from each sample.
- CCD package is flight qualified.
- X-ray tube and power supply will be flightready by next year.

Conclusions

- Miniaturized XRD is a proven technique for mineralogical analysis on flight missions.
- In the 15 years since CheMin was developed technological advances have significantly reduced analysis time.
- Based on tests with Terra CheMin-V could provide 2 mineral/geochemical analyses within 15 minutes.
- 15 minutes of analysis time on the surface of Venus with CheMin-V would result in a significant advance in our understanding of the planets geology and surficial processes.



Habitable lakes – ~3.5 Ga



Ground-truthing orbital data



- Highest hematite content of any drill sample (not by much).
- Highlights multiple controls on orbital mineral detections.



Stoer hematite content (15 wt.%)

