Petrology and Geochemistry of Venus Basalts

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Modified and updated from Filiberto and Treiman (2017) LPSC presentation

Venera 13 image

LPI

USRA

Goals

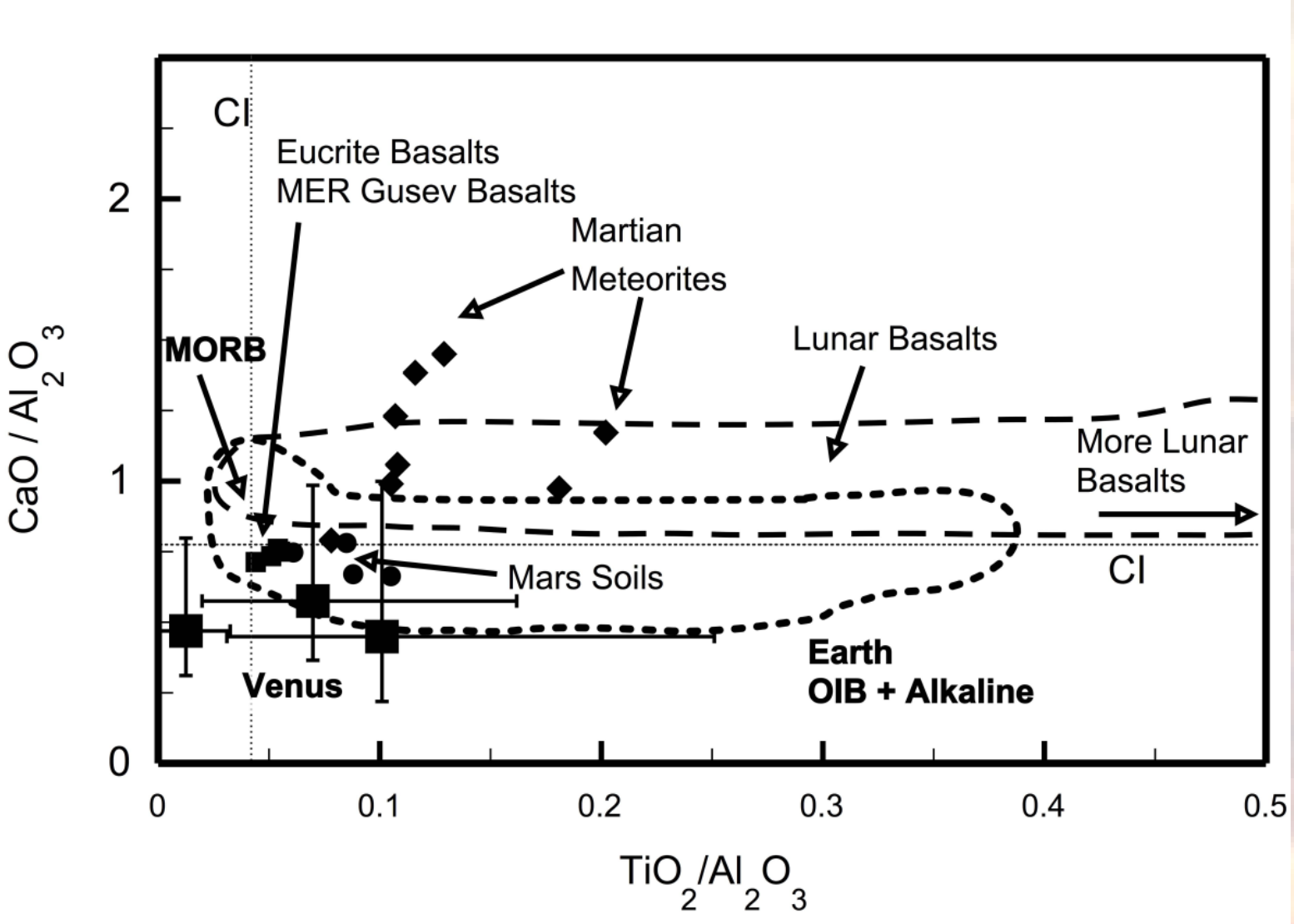
- Chemistry of Venus magmas
- Constraints on their origin
- Uncertainties in these models
- What data do we need?
  - Differentiation of Venus
  - Origin and evolution of the crust
  - Magmatism and magmatic evolution

Image from Wikipedia/http://newfrontiers.nasa.gov/images/2_06_VENUS_lg.png

Data from Venus

- Bulk chemistry from landers
  - Venera 13
  - Venera 14
  - Vega 2
- Radioactive Element Abundances in Venus Surface Materials
  - Venera 8, 9, and 10
  - Vega 1 and 2
- Orbital emissivity measurements
  - First order rock type
  - Dyar talk

Venera and Vega Data

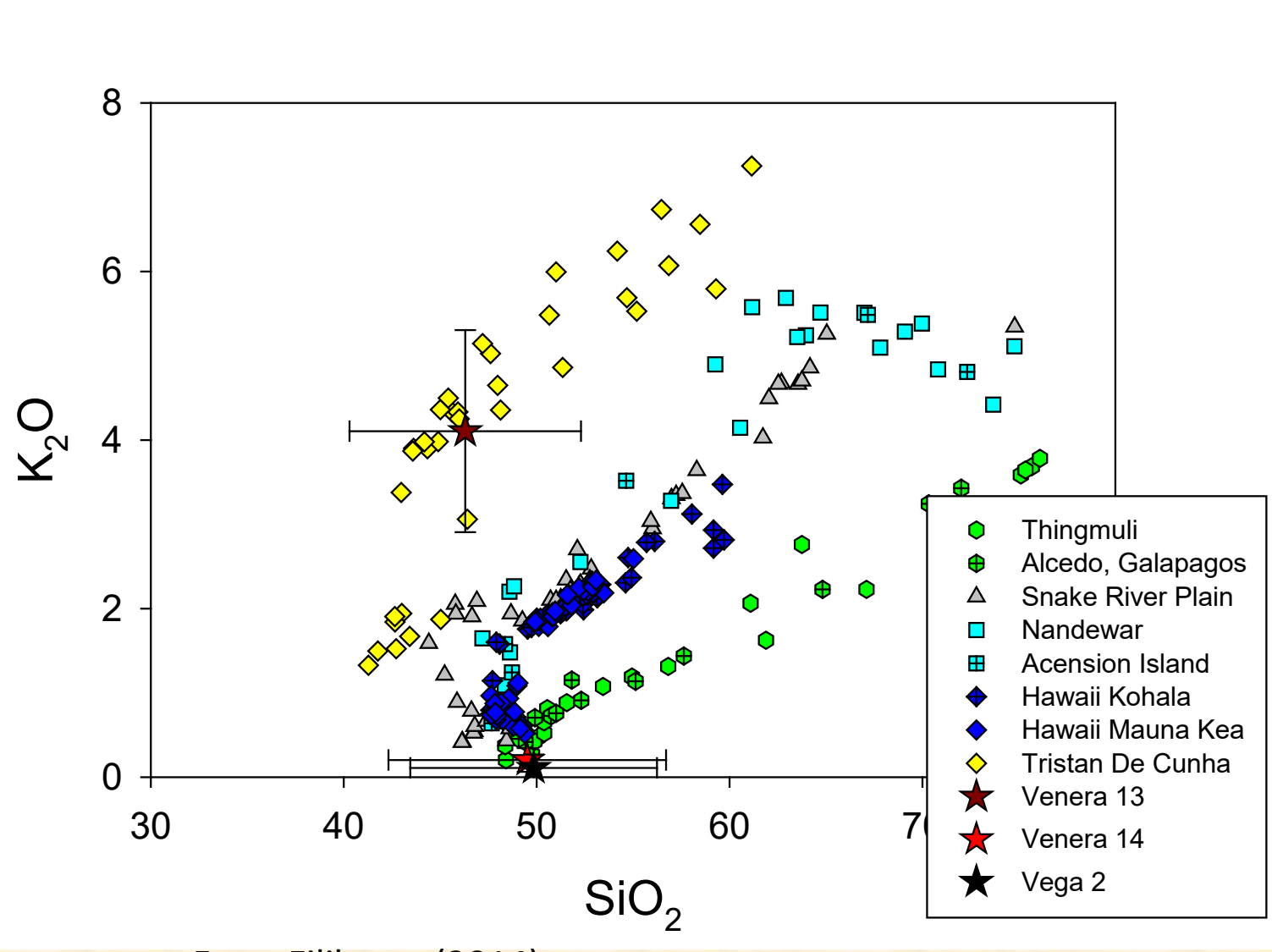


- Venera and Vega data are basaltic in chemistry
- Venus basalts are Earth-like in chemistry
- Cannot rule out similarities with Martian or lunar basalts
- Error bars are too large

- This is a first order issue
  - Origin and evolution of the crust

From Treiman 2007

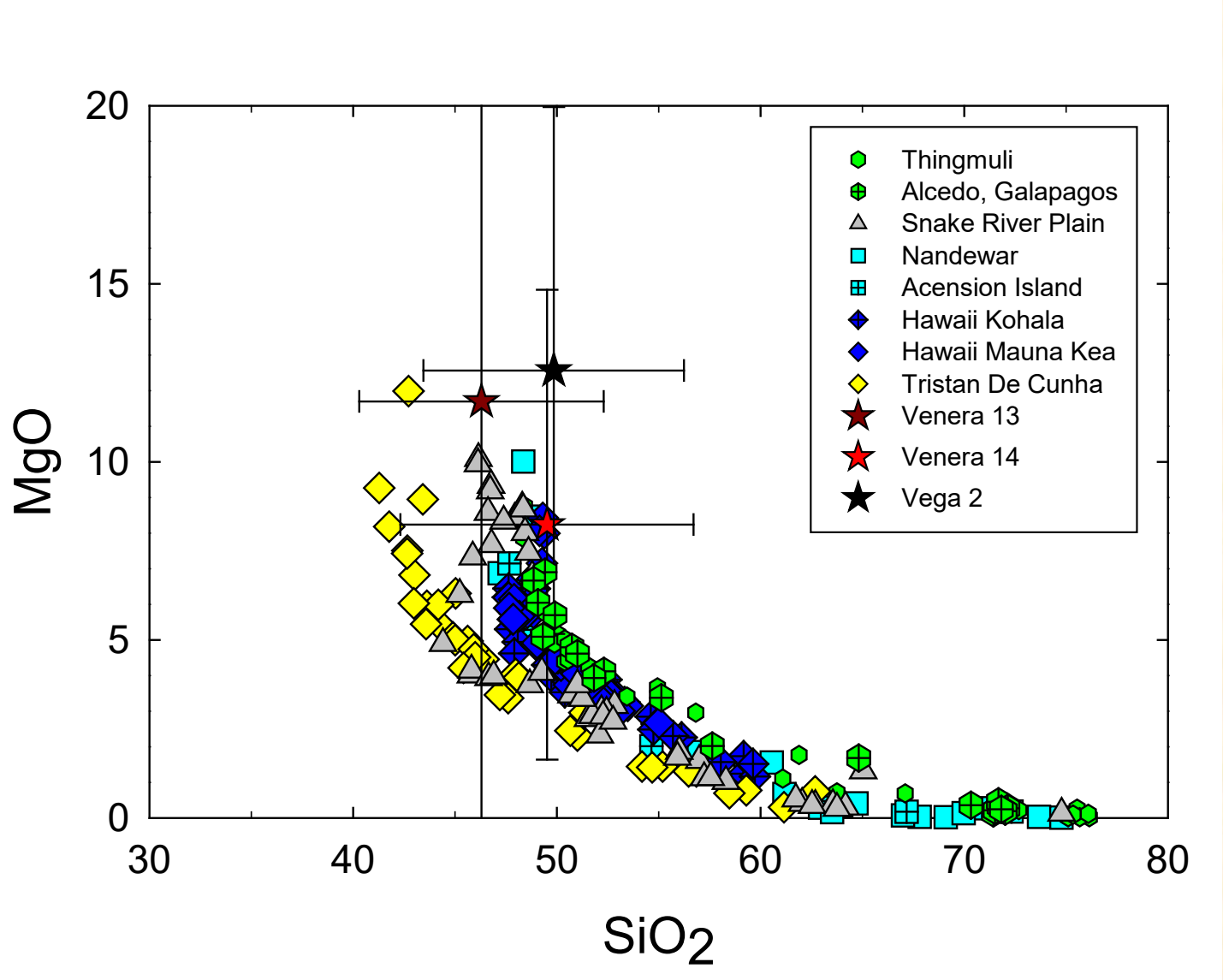
Venera and Vega Data



From Filiberto (2014)

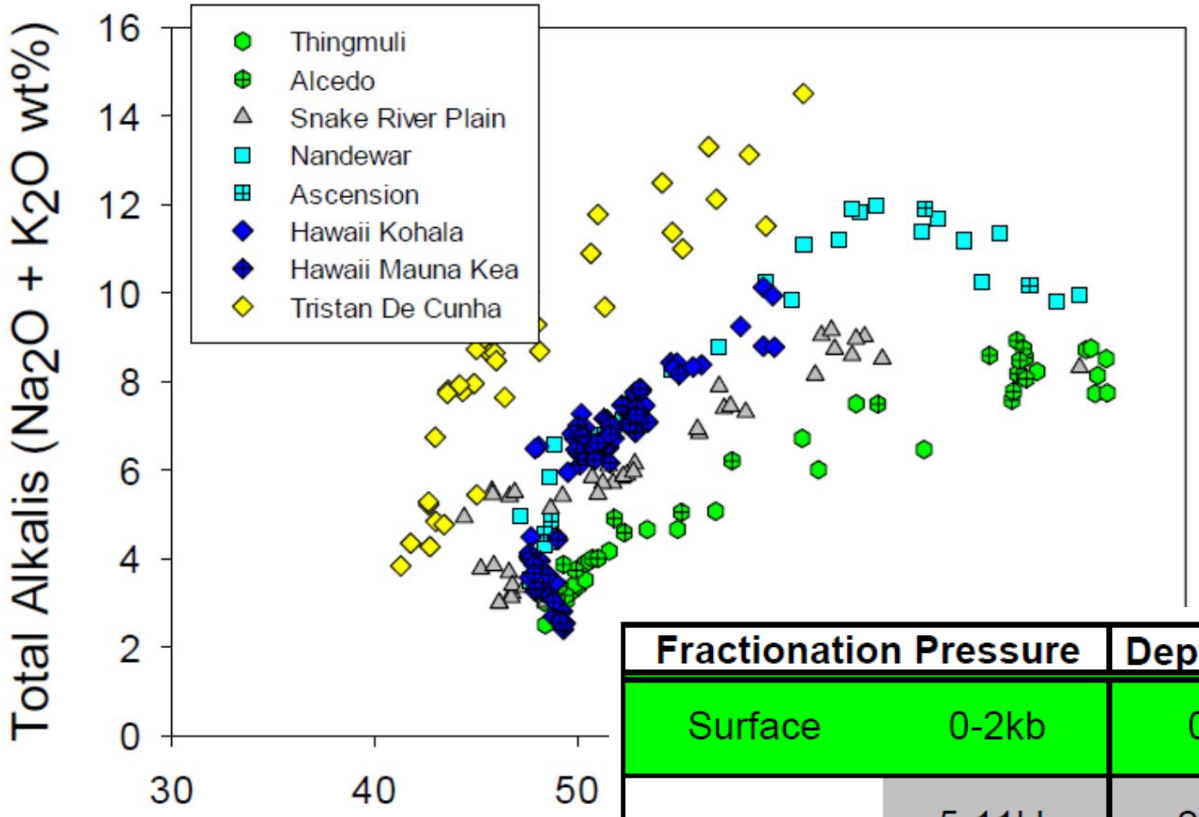
- Venera 13 – consistent with a high-K silica undersaturated basalt
- Venera 14 and Vega 2 – consistent with a terrestrial basalt
- However, 2 sigma error bars on SiO_2 prevent exact classification

Venera and Vega Data



- MgO – at detection limits for all analyses

- Precise and accurate measurements are needed for:
  - Rock classification
  - Basalt evolution:
    - Is it a primitive or evolved magma
  - Temperature of magma formation



Experimental Constraints

- Accurate and Precise data:
- Can provide information about magma genesis conditions
  - Pressure, Temperature, Volatile Content

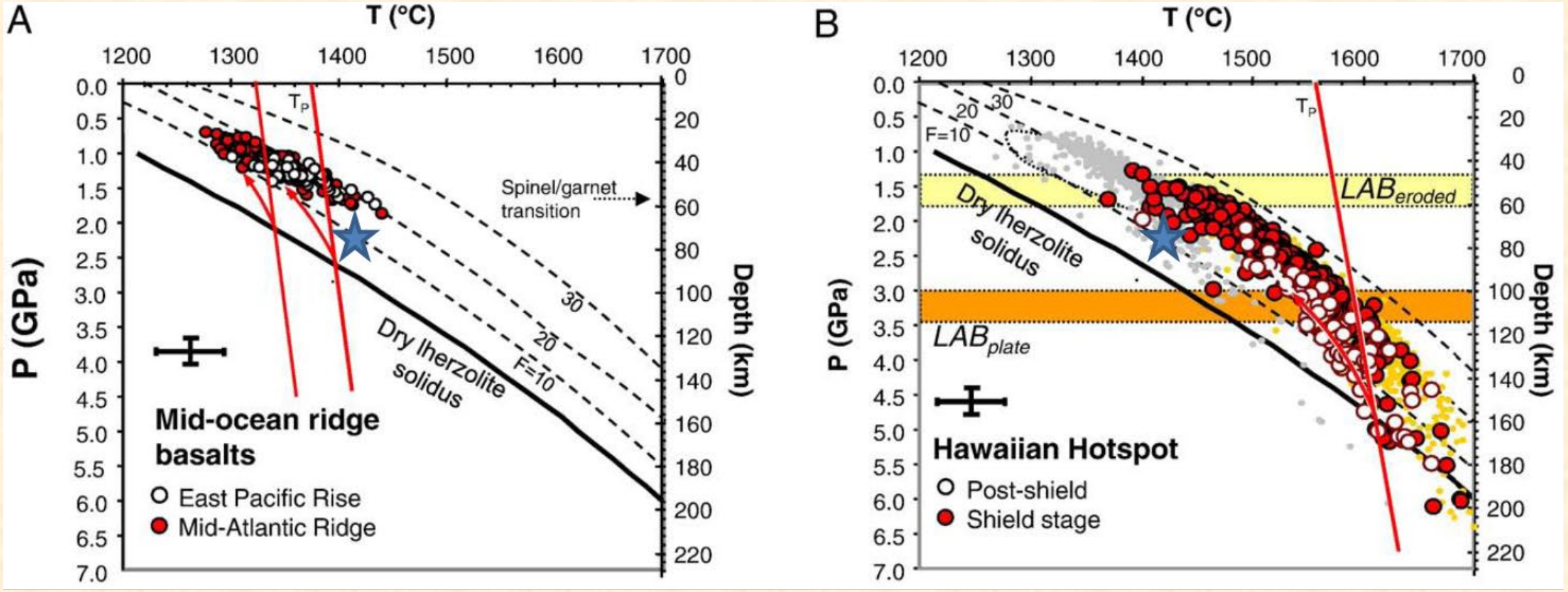
Fractionation Pressure	Depth (km)	Volatile Content	Trend	Terrestrial Analog
Surface	0-2kb	0-10	Tholeiitic Trend	Galapagos Thingmuli
Base of the crust/Upper mantle	5-11kb	20-40	<0.3wt% water	Potassic Alkalic Series	Snake River Plain
	9-11kb	30-40	>0.3wt% water	Sodic Alkalic Series	Nandewar Ascension Island
	12-16kb	45-60	>0.3wt% water	Silica-undersaturated	Hawaii
Mantle	18-27kb	65-100	~0.2 wt% water	Phonolitic Series ★	Tristan de Cunha

★ May require the presence of dissolved CO_2

Summary from Filiberto (2014)

Experimental data from: Spulber and Rutherford, 1983; Litvan 2005; Whitaker et al., 2007a,b; 2008; Rossier, 2006; Dasgupta et al. 2007; Botcharnikov et al., 2008; Nekvasil et al., 2004; Filiberto and Nekvasil, 2003; Green, 1970

Magma Genesis Conditions

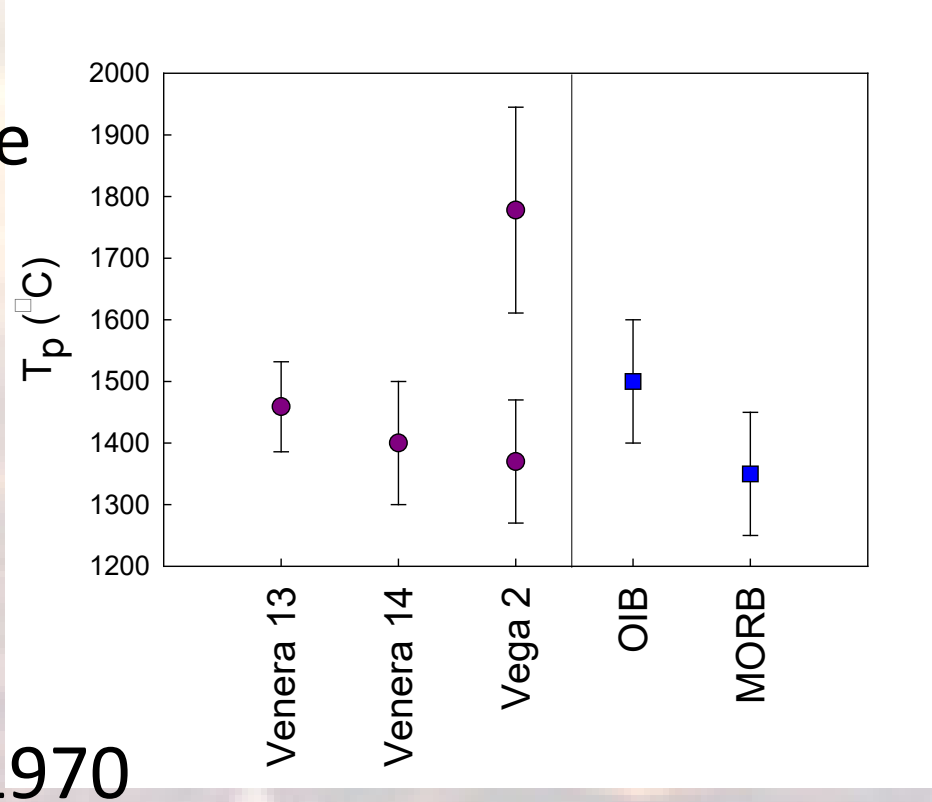


Terrestrial MORBs and Hawaii from Lee et al. (2009) with average data for Venus (blue star) from Lee et al. (2009); Weller and Duncan (2015); Shellnutt (2016)

Mid-Ocean Ridge or Ocean-Island-like?

- Vega 2 and Venera 14 analyses
  - Consistent with a terrestrial olivine tholeiite
  - Origin unknown (MORB vs OIB)
  - Need higher precision Si, Mg, and Ti

- Venera 13 analysis
  - Consistent with silica-undersaturated
  - ~0.2 wt% bulk water in the basalt, Green, 1970
  - carbon-rich source region, Dasgupta et al., 2007



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What quality data do we need from a future mission?

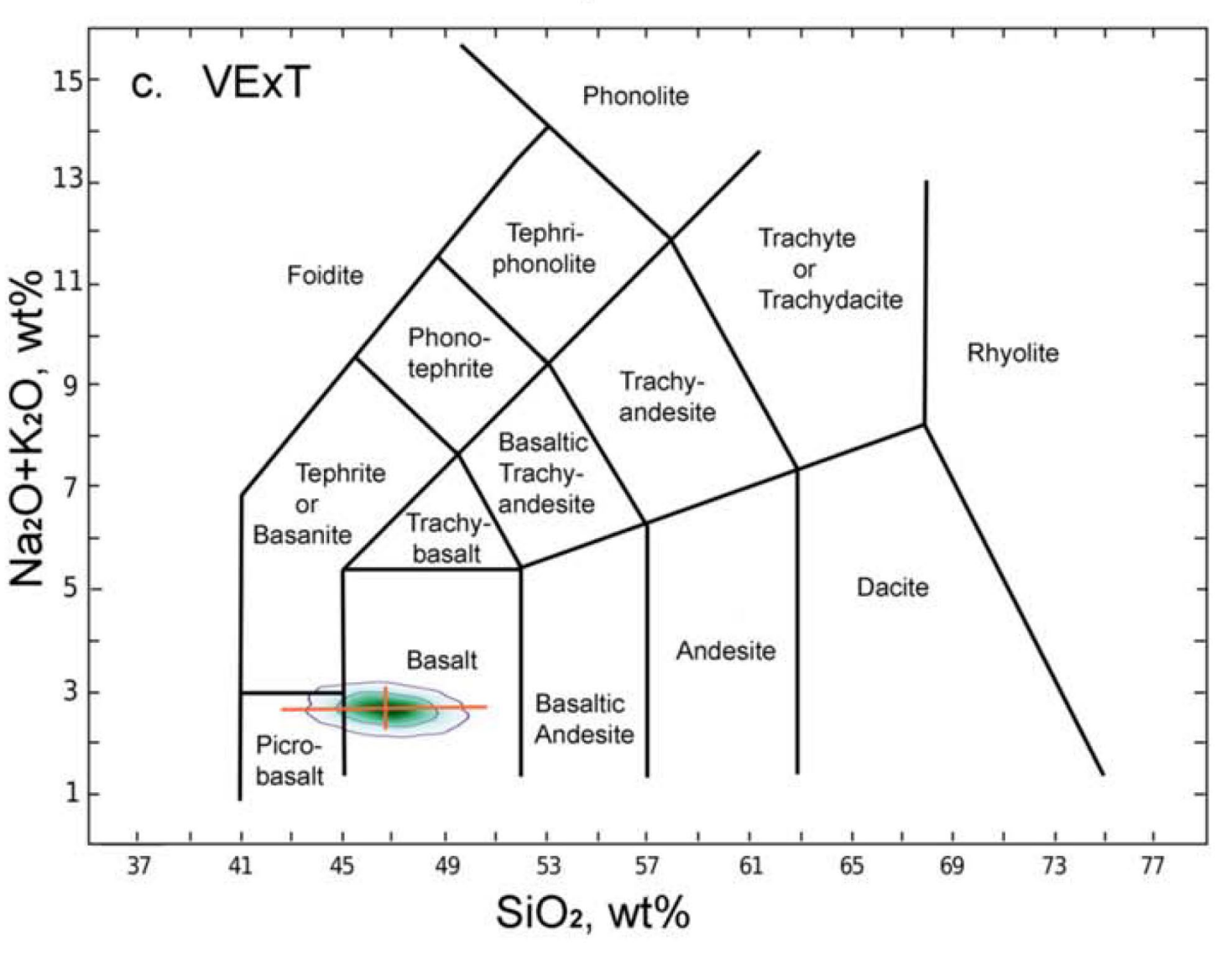
Table 2
Absolute Uncertainties in Oxide Abundances, Weight %, 1σ

	ICPOES[a]	APXS[b]			VExT[c]	LIBS[d]		
Uncertainty%	Total	Accuracy[e]	Precision	Total	Total	Accuracy	Precision	Total
SiO_2	0.35	1.48	0.27	1.50	2.00	5.10	0.53	5.13
TiO_2	0.02	0.18	0.015	0.18	0.15	0.49	0.05	0.49
Al_2O_3	0.56	0.56	0.095	0.57	1.00	3.57	0.68	3.63
Cr_2O_3	2.5	0.05	0.005	0.05	0.20	…	…	0.01
FeO	0.18	1.01	0.13	1.02	0.50	3.77	0.39	3.79
MnO	0.01	0.00	0.005	0.01	0.10	…	…	0.01
MgO	0.15	0.53	0.085	0.54	0.50	1.83	0.19	1.84
CaO	0.52	0.26	0.03	0.26	0.80	2.20	0.30	2.22
Na_2O	0.21	0.07	0.035	0.08	0.20	1.00	0.25	1.03
K_2O	0.04	0.07	0.02	0.08	0.05	0.62	0.15	0.64
P_2O_5	0.01	0.18	0.025	0.18	0.10	…	…	0.00
SO_3	0.01	1.29	0.035	1.29	0.30	…	…	0.00
Cl	0.01	0.09	0.01	0.09	0.10	…	…	0.00

- Igneous Rock classification schemes
- Magma Genesis
- Chemical Index of Alteration

From Treiman, Filiberto, Rivera-Valentin (2020)

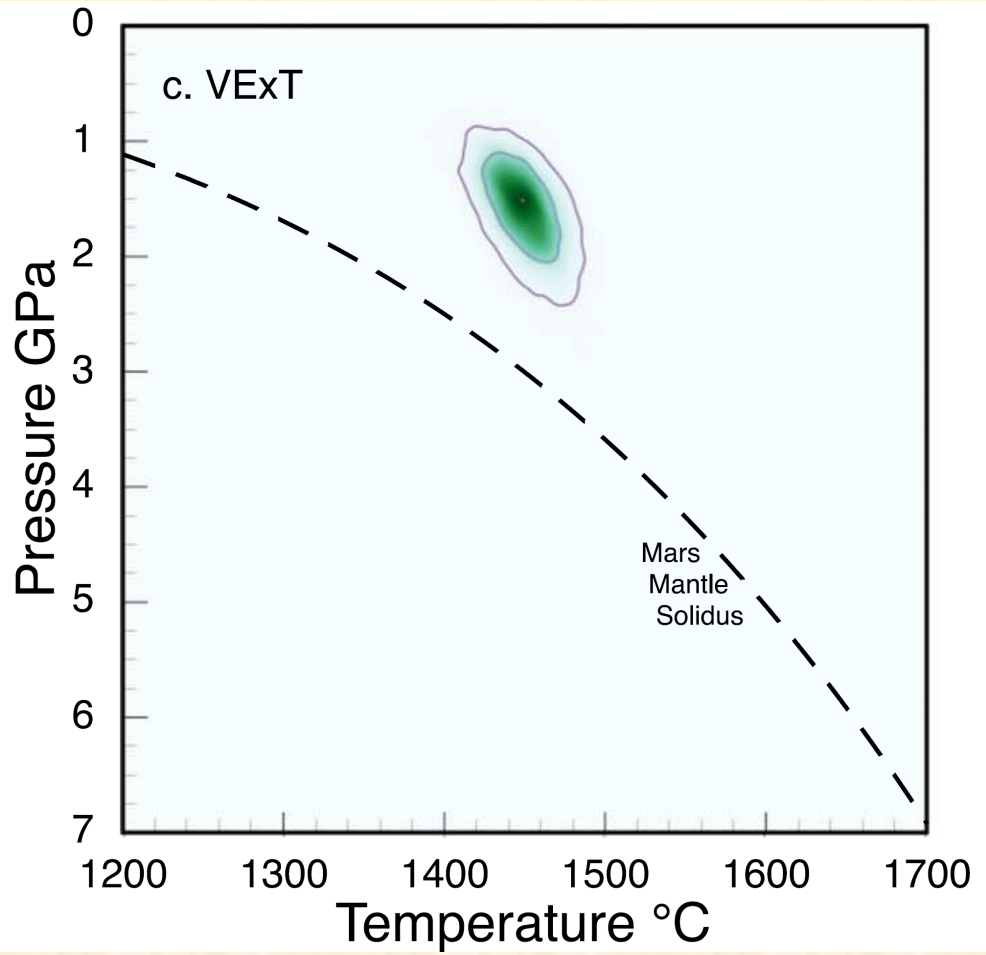
Total Alkalis and Silica



- Rock Classification
  - classify igneous rocks
  - make inferences about magma genesis conditions
  - Investigate evolution of magmas and crust
- VExT adequate at 2 sigma

From Treiman, Filiberto, Rivera-Valentin (2020)

Magma Genesis Conditions



- Pressure calculated from silica activity
- Temperature calculated from Fe-Mg exchange
- VExT adequate at 2 sigma

From Treiman, Filiberto, Rivera-Valentin (2020)

Key elements for future missions

- Na, K, Si
  - Classify igneous rocks
  - Make inferences about magma genesis conditions (T, P, XH_2O)
  - Investigate origin and evolution of the crust
- Ti and P
  - Distinguish different rock types including:
  - MORB vs OIB-style genesis
    - Mantle melting schemes
    - Interior dynamics
- Mg# (Mg/Mg+Fe)
  - Investigate origin and evolution of the crust
  - Magma genesis conditions (along with Si)
    - Temperature of the Venus mantle

These are first order questions about the origin, differentiation, and evolution of Venus

Cited Venus References

- Filiberto, J., 2014. Magmatic diversity on Venus: Constraints from terrestrial analog crystallization experiments. Icarus 231, 131-136.
- Filiberto J. and Treiman A.H. (2017) Geochemistry of Venus Basalts with Constraints on Magma Genesis. The 48th Lunar and Planetary Science Conference. Abstract # 1148.
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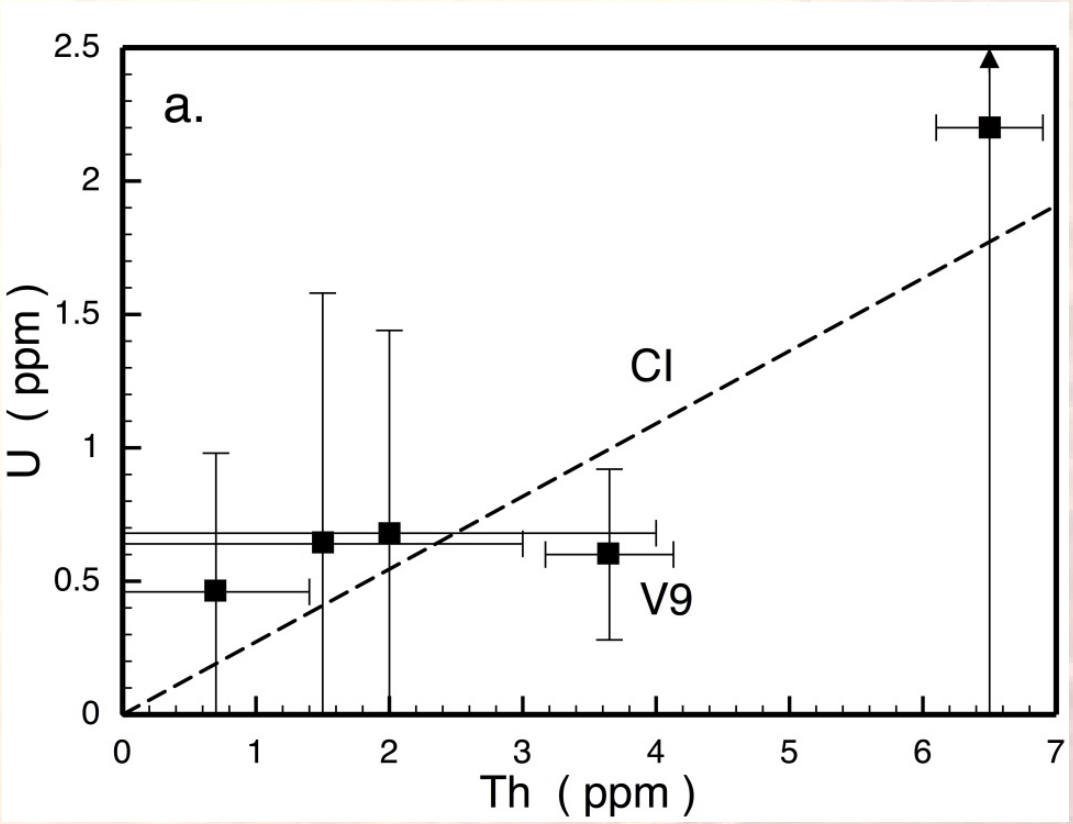
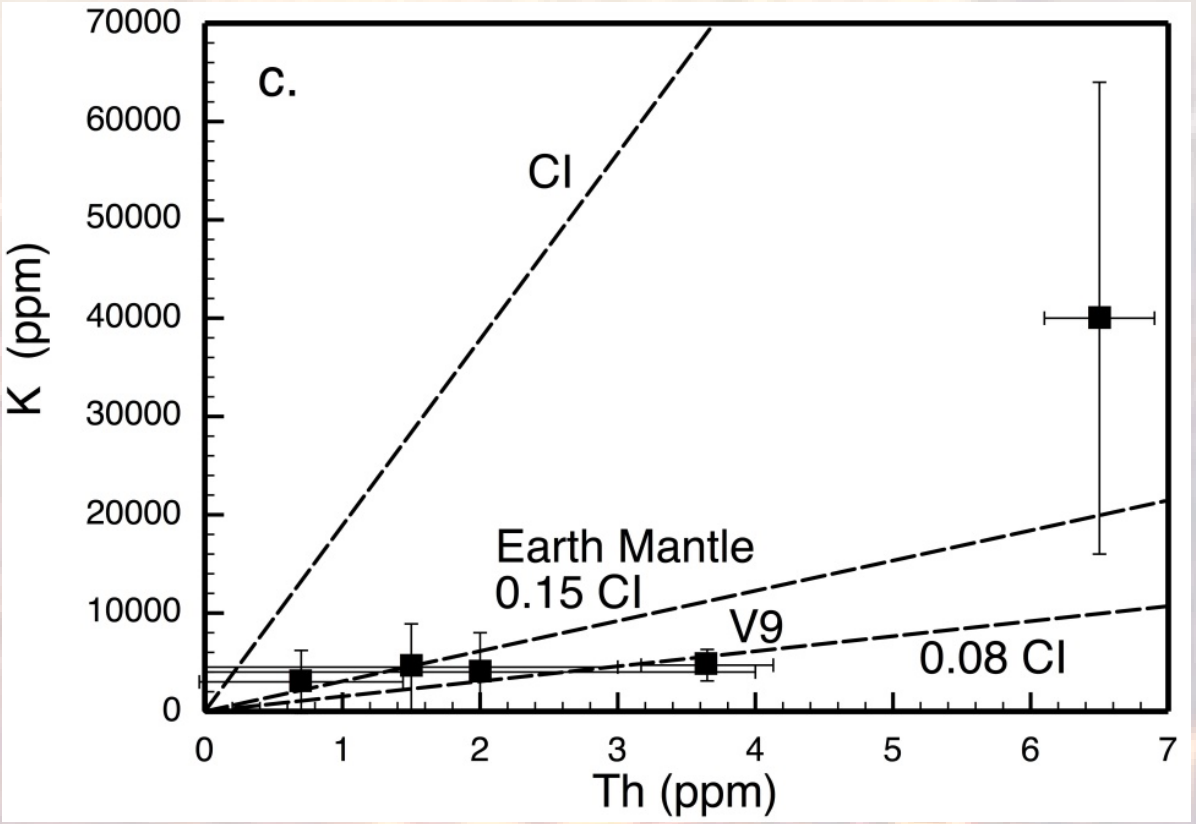
- Treiman, A.H., Filiberto, J. and Rivera-Valentin E. (2020) How Good is 'Good Enough?' Major Element Chemical Analyses of Planetary Basalts by Spacecraft Instruments. *The Planetary Science Journal.* 1 (3), 65. doi.org/10.3847/PSJ/abbc05
- Weller, M., Duncan, M., 2015. Insight into Terrestrial Planetary Evolution via Mantle Potential Temperatures, Lunar and Planetary Science Conference, p. 2749.

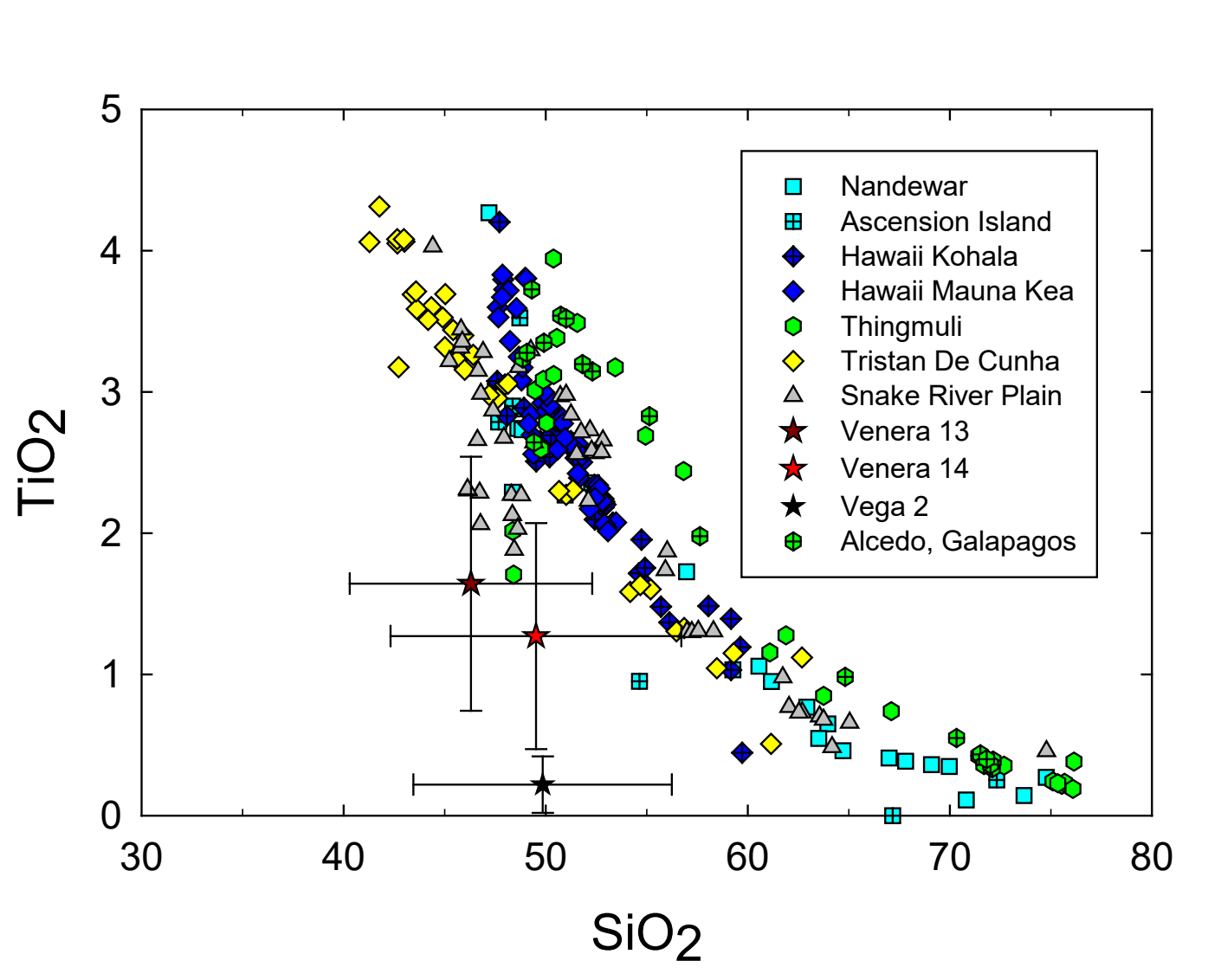
Venera and Vega Data





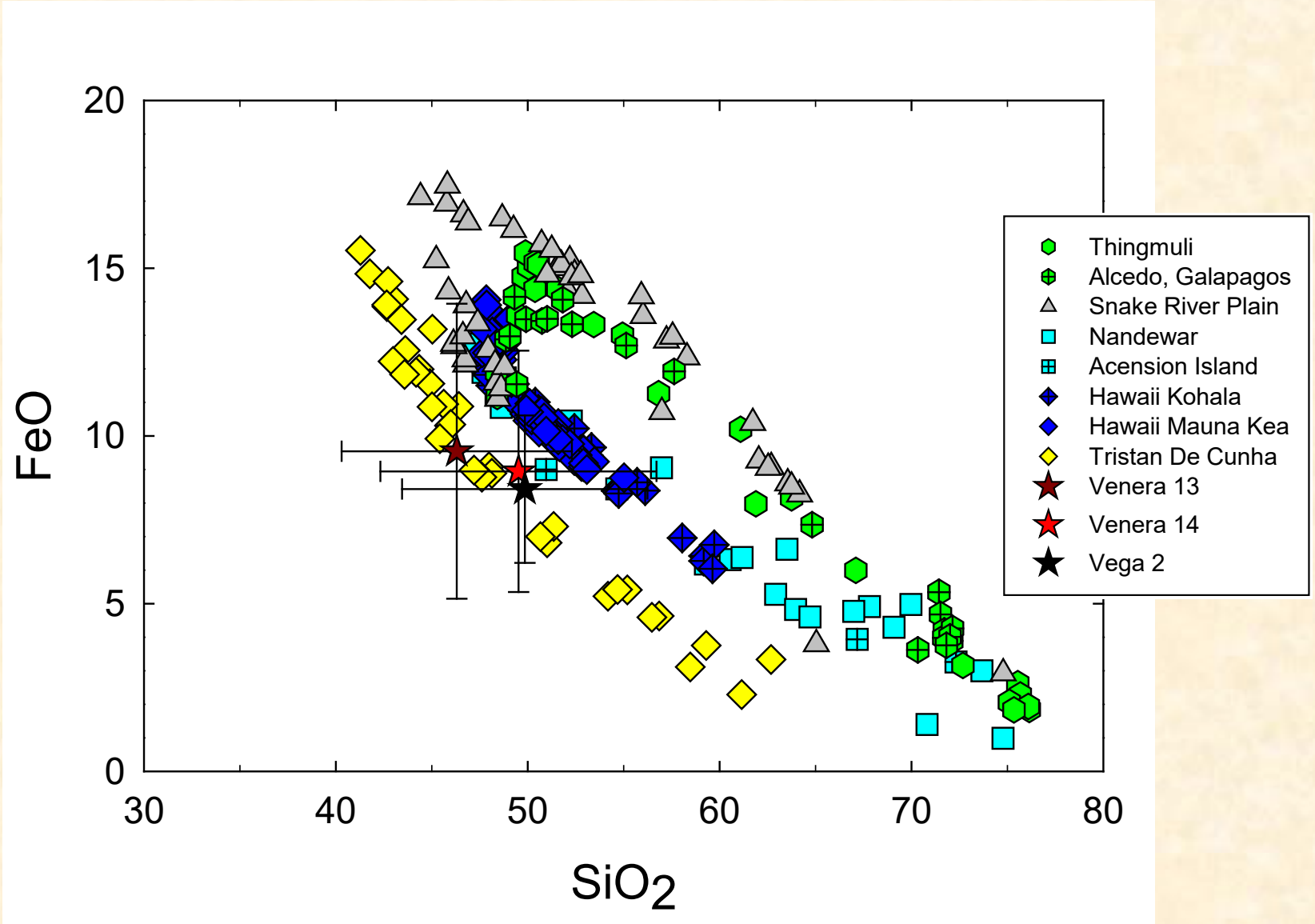
From: Treiman, A.H., 2007.

Venera and Vega Data

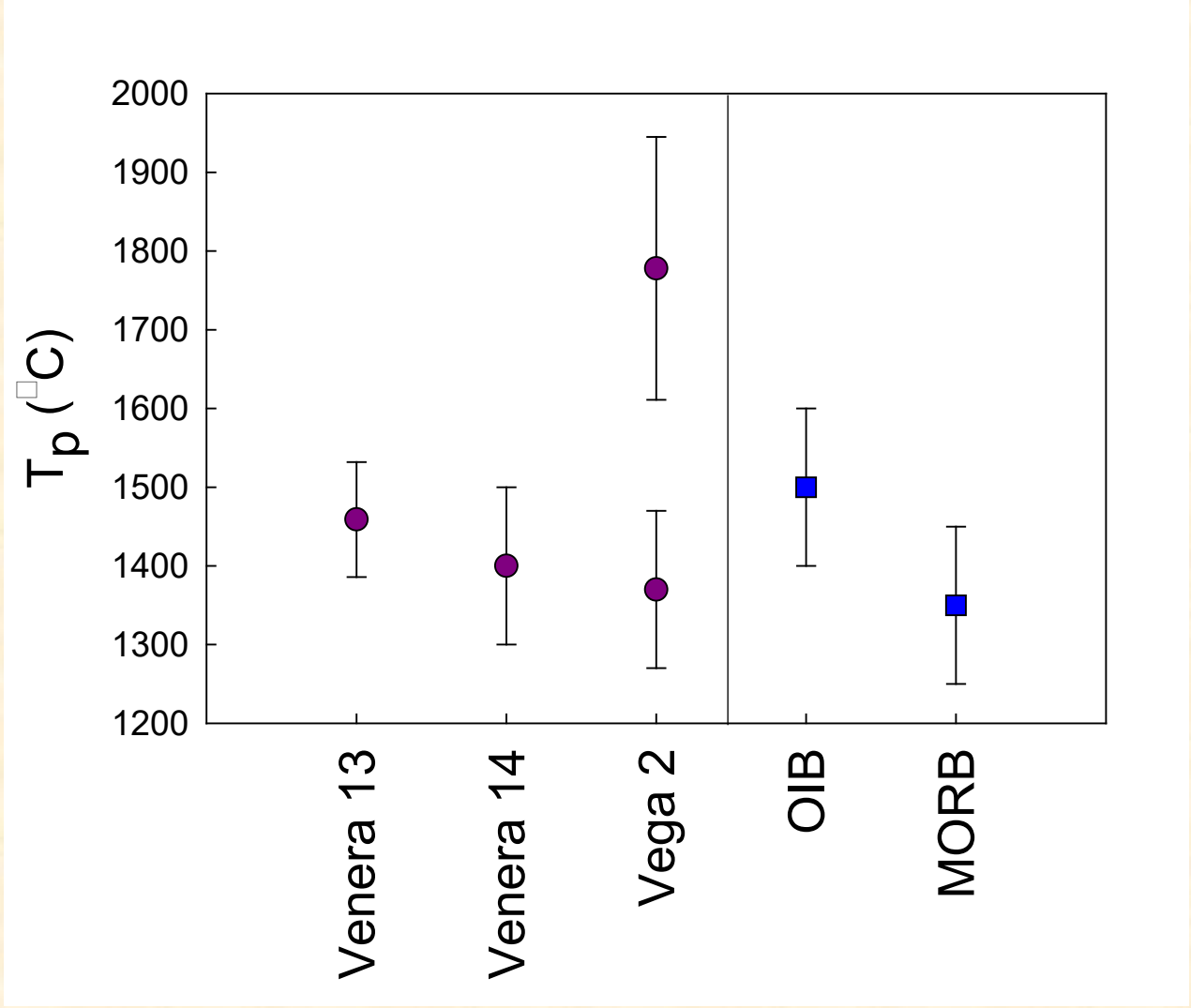


From Filiberto (2014)

FeO^T


20
15
10
5
0
FeO
30
40
50
60
70
80
SiO2
Thingmuli
Alcedo, Galapagos
Snake River Plain
Nandewar
Acension Island
Hawaii Kohala
Hawaii Mauna Kea
Tristan De Cunha
Venera 13
Venera 14
Vega 2

Mantle Potential Temperature



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