Basalt-Atmosphere Interactions on Venus - The Rocks’ Perspective

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Plan of Talk

• Hoped to have more results - sorry!
• So, a selection of research problems on Venus rock-atmosphere interactions
  – 1. Basalt-atmosphere reaction theory
  – 2. Basalt-atmosphere reaction experiment
  – 3. Carbonate-sulfate magma in Venus’ crust?
  – 4. Carbonate formation in Venus’ crust?
1. Basalt-Atmosphere Model

- Nearly all past work from perspective of atmosphere
  - CO$_2$ buffered by calcite-wollastonite-quartz?
  - NaCl buffered by sodalite-nepheline?
- Little work from other perspective - what happens to known basalt solids in Venus atmosphere? E.g.,
  - Plagioclase feldspar
  - Basaltic glass.
Example: Anorthite

- Plagioclase feldspar abundant in basalts
  - Mostly intermediate (Ca,Na), exsolves at Venus T to nearly pure
  - Anorthite (CaAl$_2$Si$_2$O$_8$) & Albite (NaAlSi$_3$O$_8$)

- Anorthite + Venus Atmosphere?
- CaAl$_2$Si$_2$O$_8$ + SO$_3$ $\rightleftharpoons$ CaSO$_4$ + Al$_2$SiO$_5$ + SiO$_2$
  - Anhydrite + andalusite + quartz !!!

- Does this reaction proceed?
  - Venus atmosphere est’d 0.2 - 0.3 ppt SO$_3$. 
Reaction Position

- From this, very possible that SO$_3$ is buffered!
- But … SO$_3$ value is not known very well - who knows what is really going on?
2. Weathering Basalt Glass: Model

• What happens to bulk basalt (e.g., glass) in reaction with Venus atmosphere?
• High atmosphere O$_2$ $\Rightarrow$ Fe oxidizes to ferric, yielding magnetite Fe$_3$O$_4$ & hematite Fe$_2$O$_3$.
• High atmosphere SO$_2$ - SO$_3$ $\Rightarrow$ all Ca goes to anhydrite, CaSO$_4$.
• What happens to remainder? Mass balance and ‘geochemical experience’ suggest:
Weathering Basalt (Glass) II

- Removing anhydrite and magnetite / hematite leaves a residue rich in Mg-Al-Si, should form:
  - Cordierite - $\text{Mg}_2\text{Al}_3(\text{Si}_5\text{AlO}_{18})$ ,
  - Enstatite - $\text{MgSiO}_3$ , &
  - Quartz - $\text{SiO}_2$ .

- Other minerals are possible, depending
  - Scapolite $(\text{Na, Ca})_4[\text{Al}_3\text{Si}_9\text{O}_{24}](\text{Cl, CO}_3, \text{SO}_4)$
  - Sapphirine $(\text{Mg, Al})_8(\text{Al, Si})_6\text{O}$
  - Spinel - $\text{MgAl}_2\text{O}_4$ .
Weathering: Basalt glass + CO₂ (from 1994!)

A-11 Synthetic Basalt, 750°C, 5 days, 1 bar CO₂

Oxide wt % (EMP)

Distance from interface µm

- FeO
- MgO
- CaO
- 20xNa2O
Basalt Glass + CO$_2$

Acid treatment removed dolomite, leaving film of nanocrystalline magnetite.

3. Ionic Melts (Carbonate - Sulfate)

- Walter 1964, Sill 1984
- Canali on Venus:
  - Komatsu, Baker 1992 ->
  - Channels,1000s of km long
  - Fluvial features
    - Meanders & cutoffs,
    - Cut banks,
    - Levees,
    - Distributary systems.
  - => Water-like fluid.
Baltis Vallis

- Total > 7000 km
- This view ~600 km

PIA00245: Venus - 600 Kilometer Segment of Longest Channel on Venus. This compressed resolution radar mosaic from Magellan at 49 degrees north latitude, 165 degrees east longitude with dimensions of 460 by 460 kilometers (285 by 285 miles), shows a 600 kilometers (360 mile) segment of the longest channel discovered on Venus to date. The channel is approximately 1.8 kilometers (1.1 miles) wide. At more than 7,000 kilometers (4,200 miles) long, it is several hundred kilometers longer than the Nile River, Earth’s longest river, thus making it the longest known channel in the solar system. Both ends of the channel are obscured, however, so its original length is unknown. … They resemble terrestrial meandering rivers in some aspects, with meanders, cutoff bows and abandoned channel segments. However, Venus channels are not as tightly sinuous as terrestrial rivers. Most are partly buried by younger lava plains, making their sources difficult to identify. A few have vast radar-dark plains units associated with them, suggesting large flow volumes. These channels, with large deposits appear to be older than other channel types, as they are crossed by fractures and wrinkle ridges, and are often buried by other volcanic materials. In addition, they appear to run both upslope and downslope, suggesting that the plains were warped by regional tectonism after channel formation. Resolution of the Magellan data is about 120 meters (400 feet).

http://photojournal.jpl.nasa.gov/catalog/PIA00245

NASA/Jet Propulsion Lab
Carbonate Lava: Kargel et al. 1994

- Oldoinyo Lengai
- Unique
- Viscosity like thin mud
- Erupt at ~820K, solid at ~760K.

http://www.crpg.cnrs-nancy.fr/Science/Lengai/lengai.mp4

Video from CRNG: CNRS-Nancy
Carbonate-rich melt in Venus

- Likely Venus geotherms X melting of O.L. magma at > 1 kbar P (> 3 km deep).
- Suggests that carbonate-sulfate melts likely near surface only with excess T - like near basalt intrusion.

- Carbonate at Venus surface unlikely - reacts rapidly to form sulfate.
- Abundant CO$_2$ gas penetrates deeper than S gases.
Suggestions for Future Work (No Conclusions !)

• Models of basalt-atmosphere equilibria
  – Single minerals & bulk rock compositions
  – Pseudo-section concept (metamorphic pet.)
• Experiments on reaction rates and products, at Venus-like conditions
• Experiments on forming carbonate-sulfate melts in Venus crust conditions
• Models of gas infiltration into, and reaction with, Venus’ crust