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Rock Magnetic and Mineralogical Analysis of IODP Expeditions 390 and 393 Basement Cores and their Implications for Fluid-Rock Interaction along the Mid-Atlantic Ridge Flank

Gilbert Hong[1], Sang-Mook Lee[1] & The South Atlantic Transect IODP Expedition 390 & 393 Scientists

[1]School of Earth & Environmental Sciences, Seoul National University, South Korea

Center for Deep-Surface Coupling of Earth

JOIDES Resolution Science Operator

1. Introduction

- The South Atlantic Transect (SAT) is a joint project consisting of IODP expeditions 390 & 393, which was held onboard D/V Joides Resolution throughout April to August 2022.
- During the expeditions, a total of 6 sites were drilled on 7, 15, 31, 49, and 61 Ma ocean crust.
- The project aims to clarify how hydrothermal fluid-rock interaction have occurred throughout time in Southern Atlantic lithosphere, and to investigate how Atlantic ocean circulation have been impacted by rapid climate change events.
- In this study, rock magnetic properties of the basaltic rocks were analyzed and compared with key magnetic mineralogy.

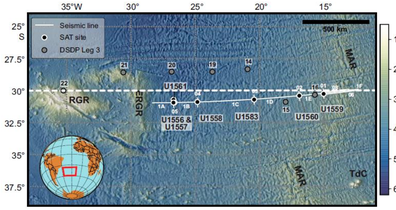


Fig. 1: SAT Drill sites and topography (Coggon et al. 2024)

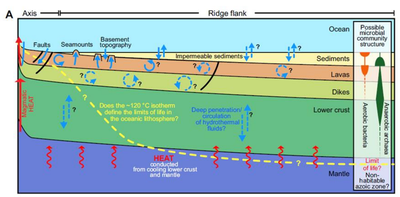
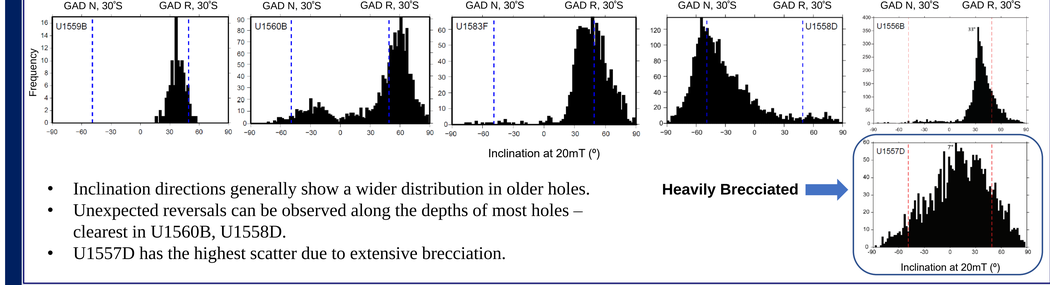


Fig. 2: Schematic diagram of the hydrothermal fluid-rock interaction along the MAR ridge flank (Coggon & Teagle, 2011)

3. Rock Magnetic Analysis

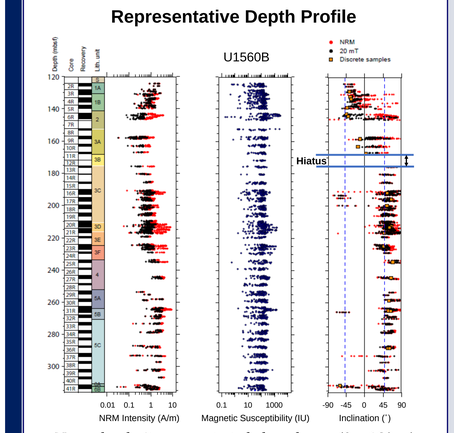
Distribution of Inclination after 20mT Demagnetization



- Inclination directions generally show a wider distribution in older holes.
- Unexpected reversals can be observed along the depths of most holes – clearest in U1560B, U1558D.
- U1557D has the highest scatter due to extensive brecciation.

Heavily Brecciated

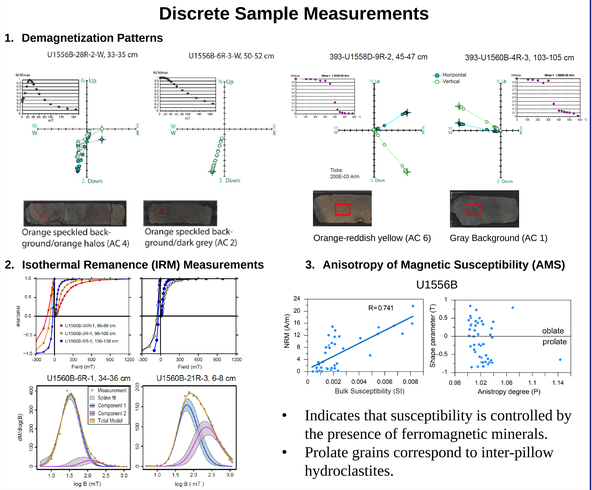
Representative Depth Profile



- Normal polarity concentrated along lower (0 – 160 m) depths.
- Discontinuity in lava accumulation observed.

Discrete Sample Measurements

1. Demagnetization Patterns



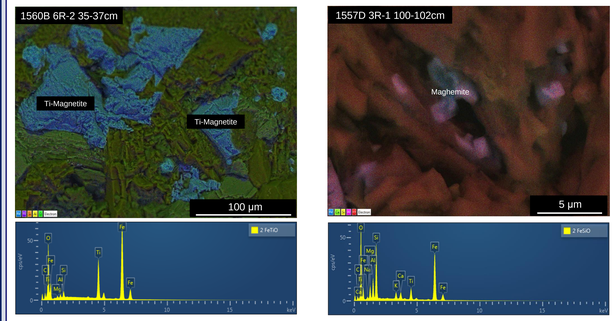
2. Isothermal Remanence (IRM) Measurements

3. Anisotropy of Magnetic Susceptibility (AMS)

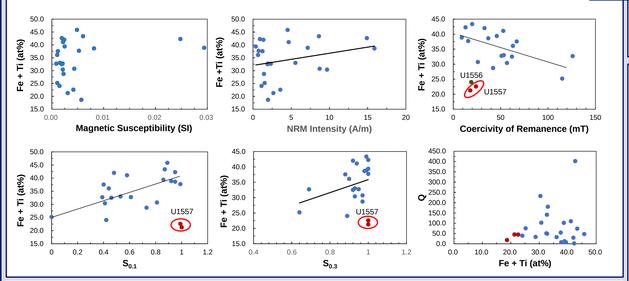
- Indicates that susceptibility is controlled by the presence of ferromagnetic minerals.
- Prolate grains correspond to inter-pillow hydroclastites.

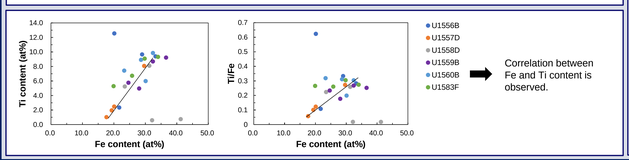
4. Mineralogy & Composition

SEM Image & EDS Spectra



Magnetic Properties vs. Composition





Correlation between Fe and Ti content is observed.

Atomic Weight Measurement

Fresh Background

2 FeTiO

Element	Line Type	Apparent Concentration	k Ratio	Wt%	Wt% Sigma	Atomic %
O	K series	23.46	0.079	32.35	0.09	60.74
Mg	K series	0.26	0.002	0.72	0.02	0.90
Al	K series	0.39	0.003	0.85	0.02	0.94
Si	K series	0.75	0.006	1.32	0.02	1.41
Ti	K series	11.08	0.111	13.22	0.04	8.29
Fe	K series	40.65	0.407	51.54	0.08	27.72
Total:				100.00		100.00

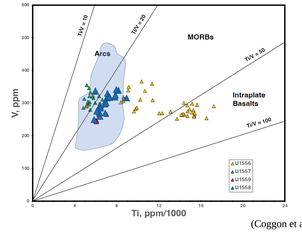
Altered Basalts

2 FeSiO

Element	Line Type	Apparent Concentration	k Ratio	Wt%	Wt% Sigma	Atomic %
O	K series	30.93	0.104	40.00	0.17	62.36
Na	K series	0.40	0.002	0.96	0.06	1.04
Mg	K series	1.60	0.011	3.86	0.06	3.96
Al	K series	2.32	0.012	4.70	0.06	4.35
Si	K series	6.19	0.049	11.00	0.07	9.77
K	K series	1.30	0.011	1.54	0.03	0.98
Ca	K series	1.43	0.013	1.69	0.03	1.05
Ti	K series	2.93	0.029	4.00	0.05	2.08
Fe	K series	23.33	0.233	32.25	0.13	14.40
Total:				100.00		100.00

- Significantly lower grain size in altered basalts.
- Alteration of igneous rocks accompanied maghematization of magnetic minerals.
- Both Fe and Ti content are lower in more oxidized magnetic mineral grains.

Relation with Geochemical Data



(Coggon et al. 2024)

- Changes in magnetic properties and composition of magnetic minerals during alteration corresponds with the geochemical data, which shows a tendency of SAT basalts evolving from MORB to arc-like basalt.

2. Sites & Procedure

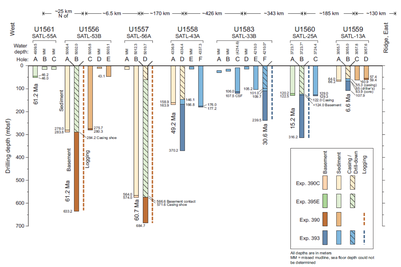


Fig. 3: Drill sites and depth of the holes drilled during SAT (Coggon et al. 2024)

- Rock magnetic measurements (AMS measurements, remanent magnetization, AF & thermal demagnetization etc.) made onboard D/V Joides Resolution (a-c).
- Mineralogical observations and composition measurements were conducted post-cruise using an FE-SEM equipped with an energy dispersive spectroscopy (EDS) meter located at Seoul National University (d).
- Key magnetic and mineralogical properties (Fe & Ti content, coercivity, magnetic susceptibility etc.) have been compared to establish possible correlations.

5. Summary

1. Rock magnetic properties of SAT basalts seems to be heavily affected by fluid-driven alteration.
2. Key magnetic properties such as NRM intensity and coercivity show correlation with Fe content within magnetic minerals, though there are other components (e.g., overall mineral content and grain size) that may affect the correlation patterns.
3. A clear correlation can be observed between Fe and Ti content, implying that Ti mobility was established during the alteration of magnetic minerals.
4. Such correlations also correspond to the geochemistry data, which implies an evolution of SAT basalts from MORB to arc basalts.

References

Coggon, R.M., Teagle, D.A.H., Sylvan, J.B., Reece, J., Estes, E.R., Williams, T.J., Christeson, G.L., and the Expedition 390/393 Scientists, 2024. South Atlantic Transect. Proceedings of the International Ocean Discovery Program, 390/393: College Station, TX (International Ocean Discovery Program). https://doi.org/10.14379/iodp.proc.390393.2024

Coggon, R.M., and Teagle, D.A.H., 2011. Hydrothermal calcium-carbonate veins reveal past ocean chemistry. TrAC Trends in Analytical Chemistry, 30(8):1252–1268.

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For further inquiries & questions, please contact the presenting author:
Gilbert Hong (hongfellow@snu.ac.kr).