Evaluating Temperatures and Pressures in the Bingi Bingi Point Complex Granitoid during Late-stage Magmatic Differention

-Magma Residue that Farmed Wave-like Layered Structures in Amphibole-

Hyogo Prefectural HimejiHigashi Senior High School

Kazuya Kawakatsu Sawa Matsuoka Ayumi Yamaguchi

Yukino Tsujimoto Daiki Nishikawa Kazuma Fujimoto

Keywords

Hydrothermal residual liquid ･･･ The residual liquid composed of H2O that remains after the complete crystallization of various minerals during magma differentiation.

Progressive oxidation ･･･ Oxidation that proceeds gradually or continuously under oxidizing conditions.

Subsolidus ･･･ Temperature and Pressure after minerals have crystallized completely.

Patchy zoned structure ･･･ Mottled structure that was formed by the crystal developed rapidly

Oscillatory zoned structure of amphibole

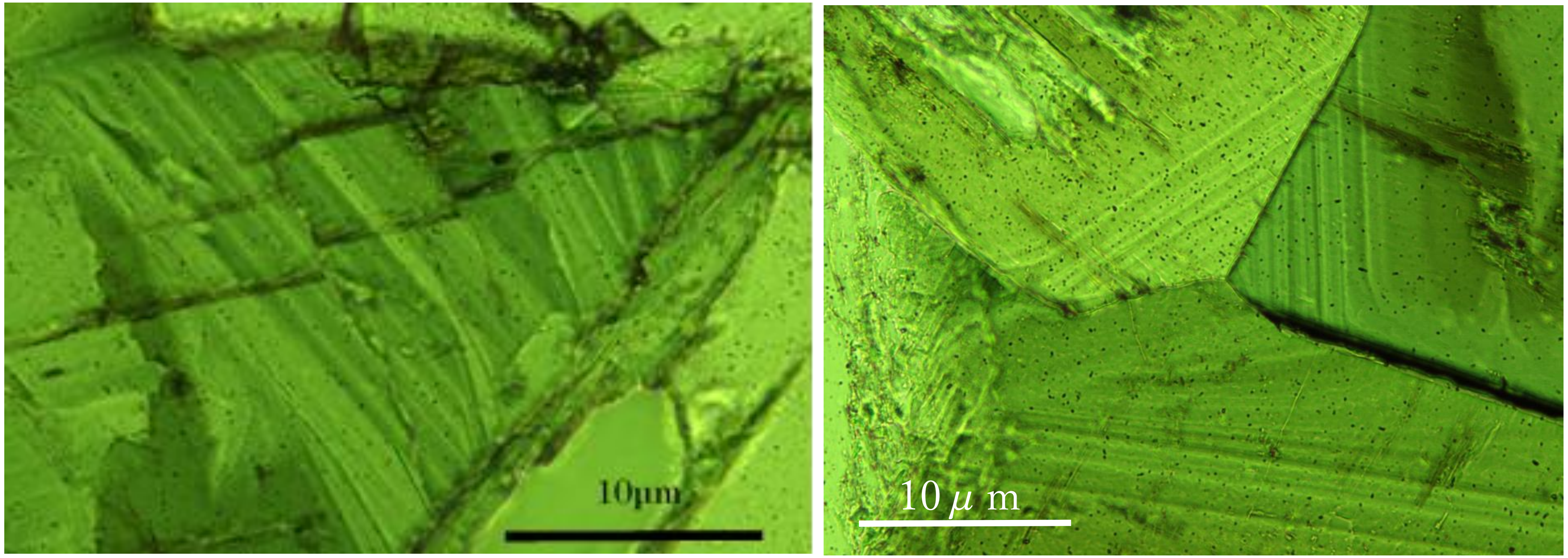


Fig1: Oscillatory zoned structure of amphibole

■OZSs are structures developing band-like structures repeatedly.

■They are formed by ion substitution as the rim of the pre-crystallized amphibole re-equilibrates due to the circulation of hydrothermal residual liquid.

Motive of this study

Mr.Kawakatsu, Science Club Advisor, Himeji Higashi High School, discovered OZSs from amphiboles of plutonic rocks first time in the world.(Geochi.Cosmoci.Acta,1987[1)])

Nevertheless

No reports of finding OZSs have been made since then.

Inspired by his research, our science club decided to develop it further in our own study.

Motive and background①

The discovery in Sanin-Belt by Kazuya Kawakatsu and Sanyo- Belt by Himeji Higashi Highschool

According to previous studies of Sanin–Belt and Sanyo–Belt, OZS, which formed secondarily by circulation of hydrothermal solution was proved in this area.

Would OZS be possible to show circulation of hydrothermal solution?
What should we do to indicate effectiveness of OZS in worldwide?

First, to Australia for the discovery of OZS !

Motive and background②

In 2024, we conducted an outcrop survey, created a geological map, and collected rock samples at Bingi-Bingi Point southeastern New South Wales, Australia.

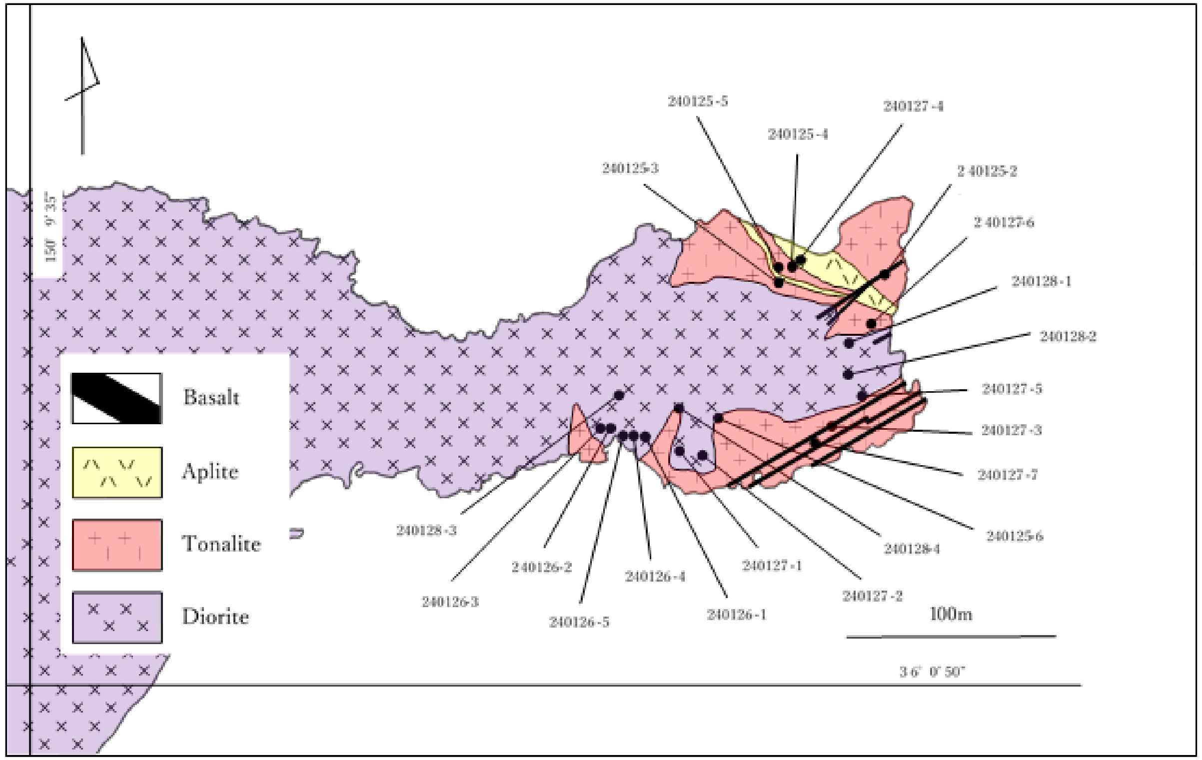
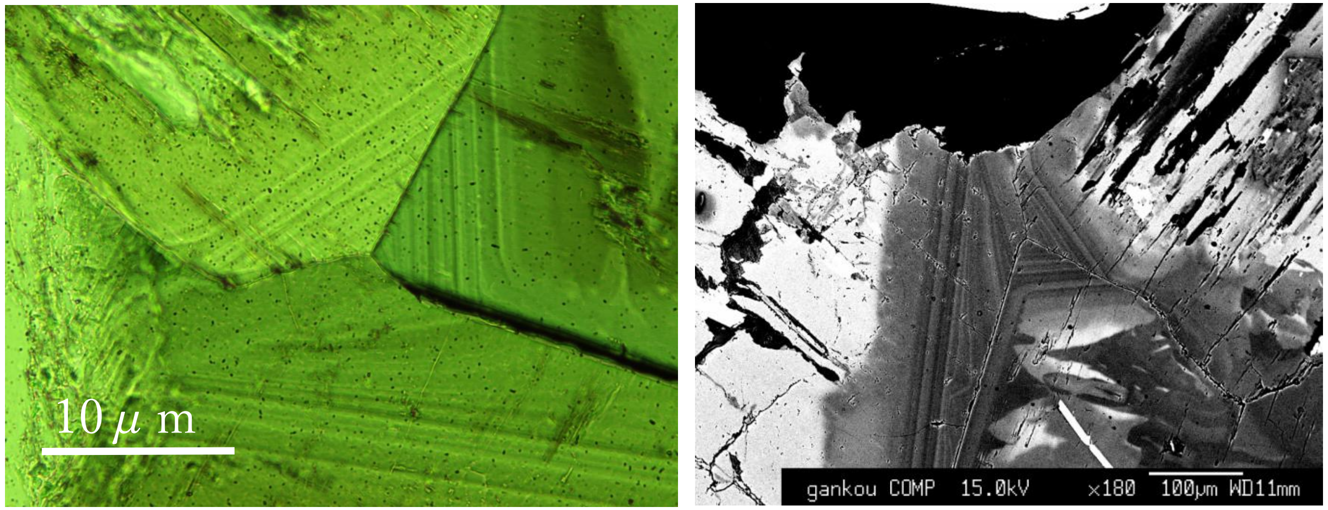


Fig.2: Created a geological map

We discovered a lot of OZSs in amphibole in diorite and tonalite as well as our hypothesis.[3)]



sample2401275

Fig.3: An example of amphibole's OZS in the diorite in contact with tonalite (left: PPL, right: BSE image)

The propose of research

- With EPMA
  - ・The Al(VI) content in hornblende is less than 0.6 and The Cl content is extremely trace.
  - ・The coupled Edenitic substitution patterns in the OZSs dominate.
  - ・The Mg/(Mg+Fetotal) gradually decreases from the core to the rim.
- These features similar South West Japan.

We estimated magma is vesiculated・dehydrated associated with circulation of hydrothermal residual liquid in subsolidus and oxidizing environment and OZS was developed in pale-green rim [3).

The propose of research

We presented the result at
American Geophysical Union and Japanese
Geological Society etc……

Got highly regarded!

Is it really subsolidus condition?

We will make a pressure and temperature clear in detail through geothermometer as paying attention to the amphibole with OZS and coexisted minerals for comfiming whether hydrothermal solution circulated in subsolidus and oxidizing environment.

To study

■We passed COCOUS-R, which is a program that supports studying.

■We analyzed the samples in Kyoto University Faculty of science on February 1st, 2nd and March 25th.

Fig.4 :The scene of EPME

Results①

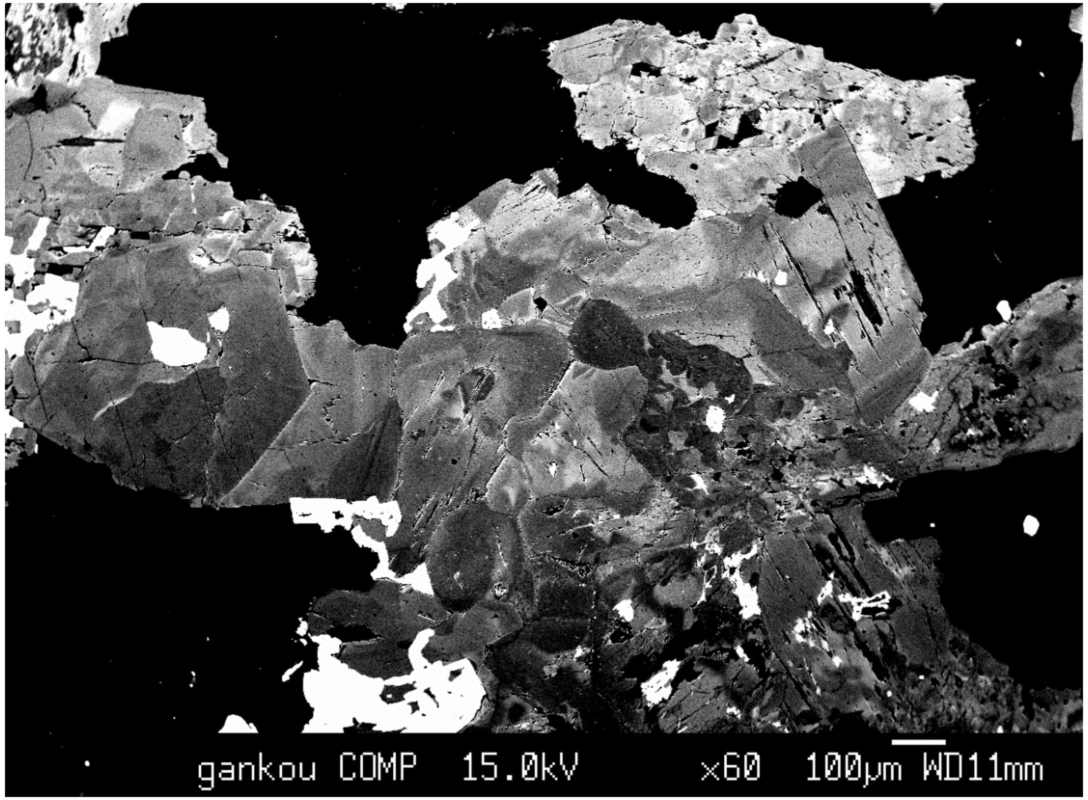


Fig.5: Amphibole with well-developed patchy zoned structure（sample240126-5 ）

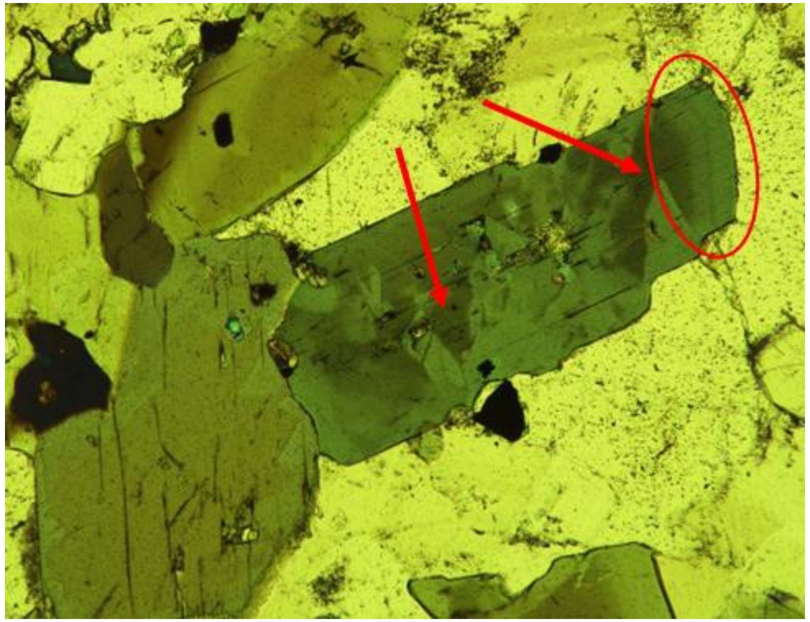
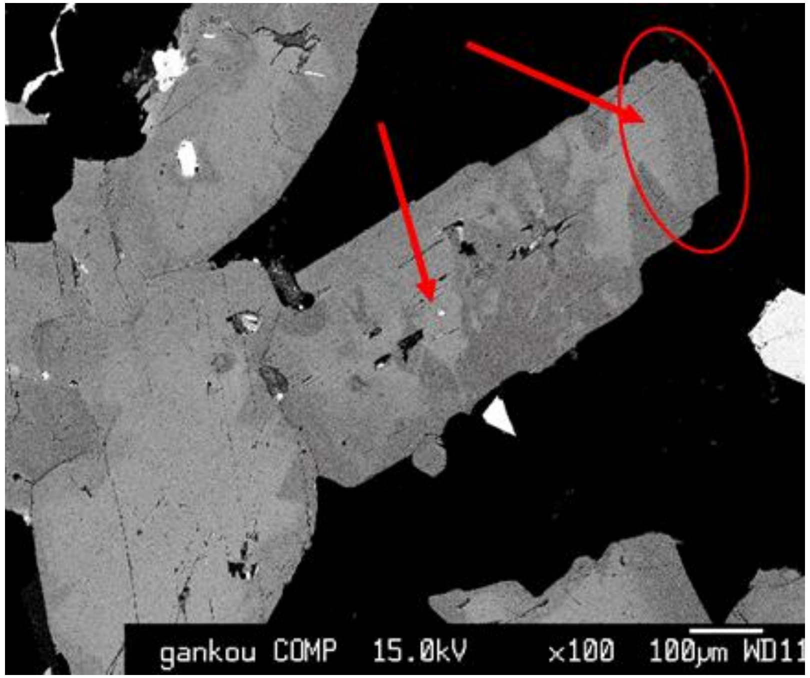


Fig.6: Amphibole with well – developed OZS and patchy zoned structure.
（sample240126-5 ）



- ■ <u>Almost all amphibole are euhedral or subhedral.</u>
- ■ <u>All OZSs develop in pale-green rim.</u>
- ■ Some core of magnesio-hornbrende have <u>patchy zones structure.</u>

Results②

- We analyzed plagioclase and alkali–feldspar existing with amphibole holding OZS, and OZS in magnesio–hornblende.
- The rim of plagioclase existing with the amphibole have reaction rim with alkali–feldsper.
- Almost all opaque minerals are pyrite.

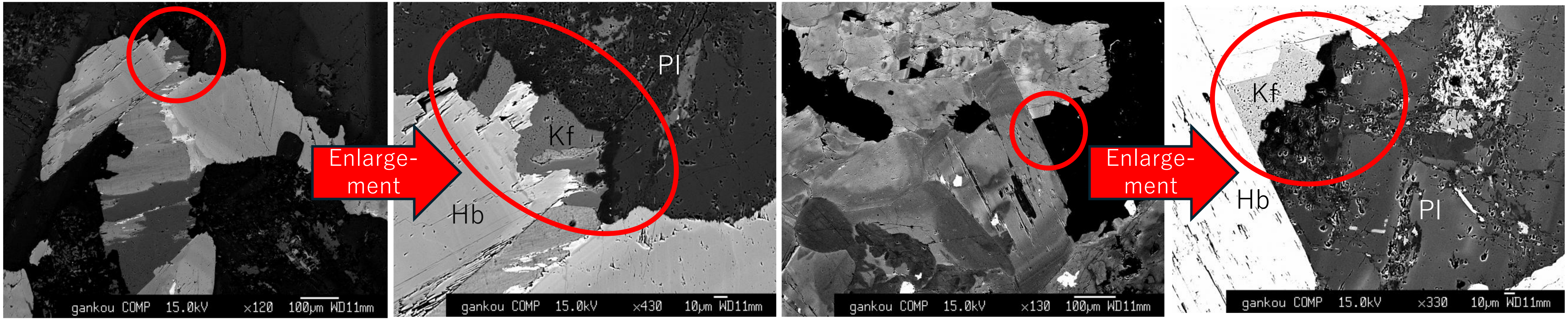


Fig.7: amphibole having OZS (Hb) coexisted two–feldspers (Pl、Kf)
(reaction–rim is shown around alkali–feldspar in contact with plagioclase)

From amphibole

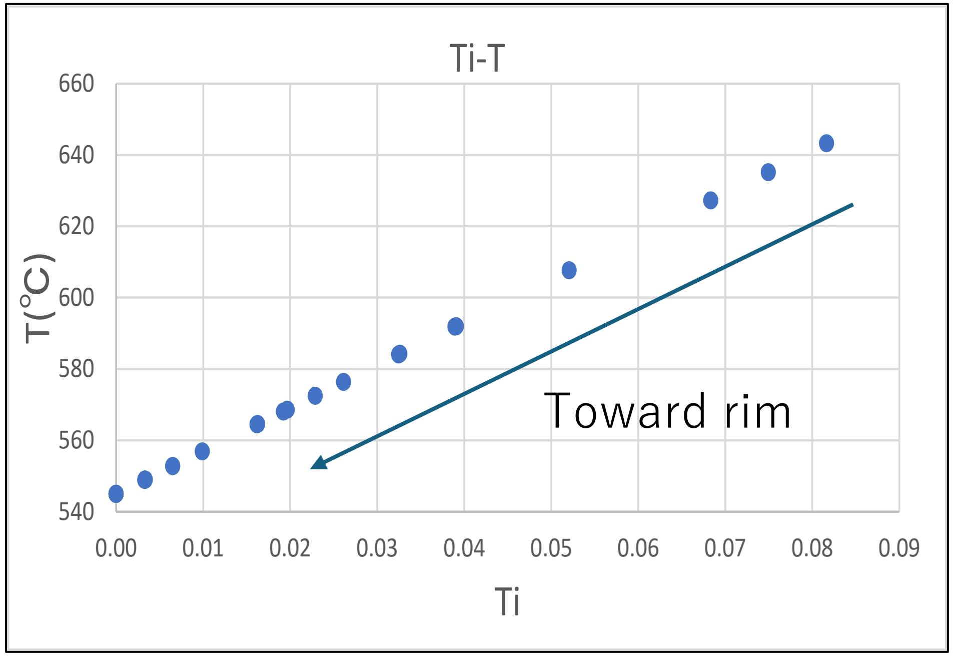


Fig.8: Geothermometer by Ti[4)]

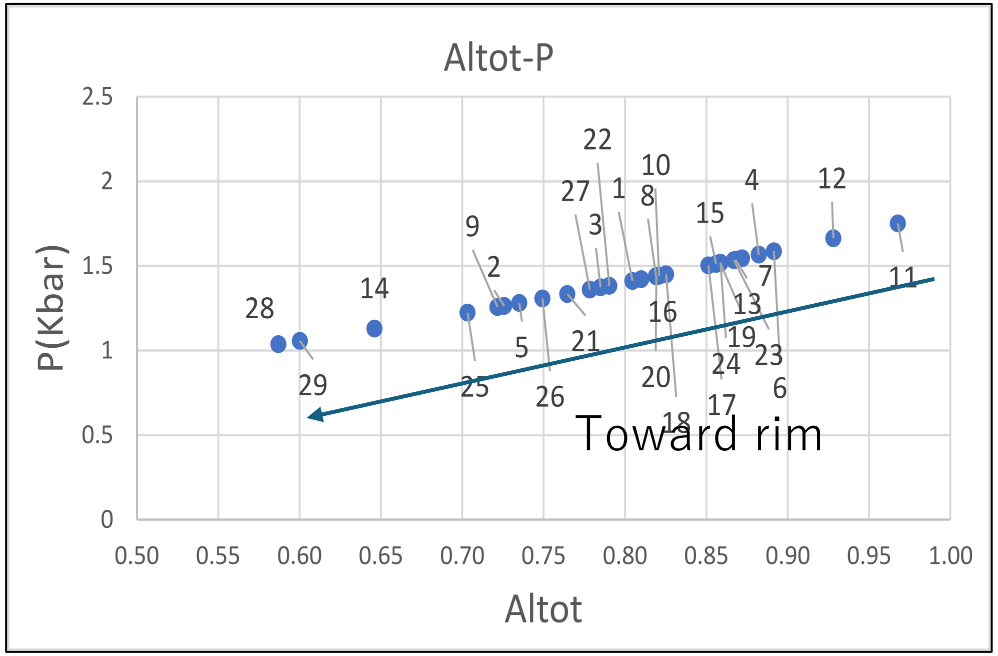


Fig.9: Geobarometer by use Al[5)]

■ Geothermometer by Ti in amphibole show a temperature range from **640℃ to 545℃** from rim to outside.

■Geobarometer by Al in amphibole show a pressure range from **1.7kbar to 1.0kbar** from rim to outside too.

From two-feldspar

- According to geothermometer which utilizes plagioclase and alkali-feldspar coexisting with OZS, a temperature is under 400℃ in 1kbar, and under 500℃ in 10kbar.

**In any case,
results show Subsolidus.**

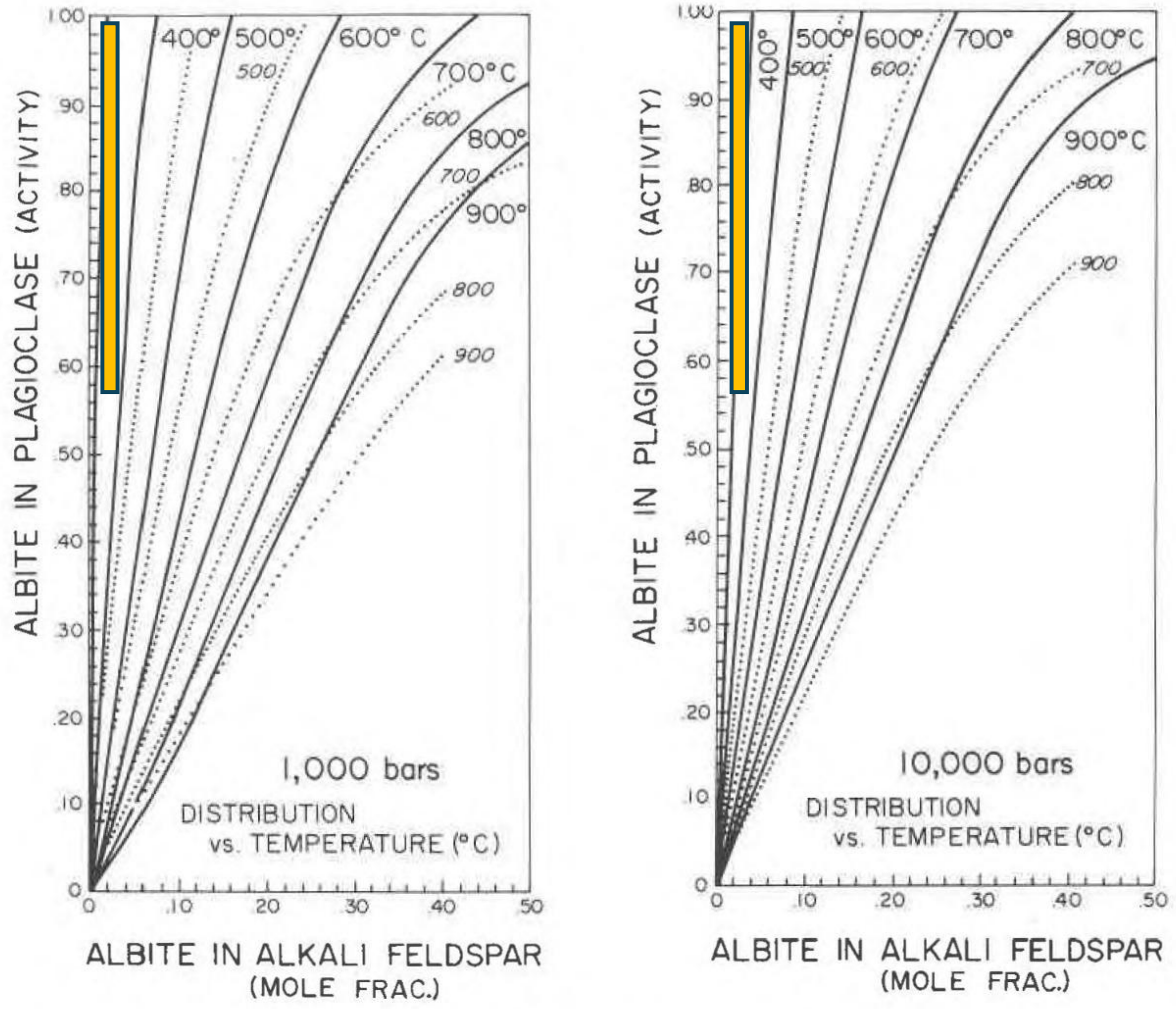


Fig.10: Exist temperature in Geothermometer which utilizes plagioclase and alkali-feldspar [6)]

Fugacity

- Almost all opaque minerals are pyrite ,and a few (opaque minerals) are magnetite and ilmenite.

- According to diagram of $\log fS_2$–$\log fO_2$ when pyrite, magnetite and ilmenite coexist at the same time, the fugacity shows the AB line.

- In this case, $\log fS_2$ is −3.5 to −2.5 and $\log fO_2$ is −19.5 to −19.0.

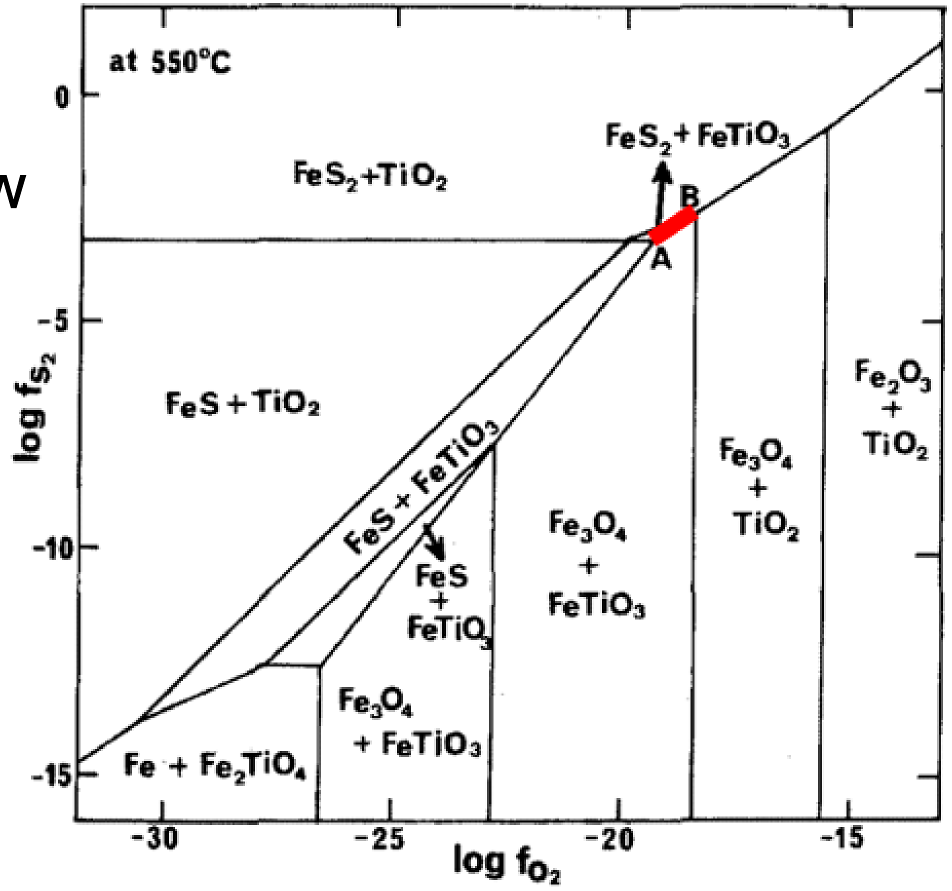


Fig.11: Fugacity of opaque minerals assembly[7)]

Discussion①

From diorite

①**Some Amphiboles are euhedral.**
→Crystallization started early magma differentiation.
②Some Amphiboles have **patchy zoned structures**.
→**Amphibole grew rapidly.**
③Many euhedral Sulfur-containing minerals(Almost all are pyrite) are crystallized while magma differentiation.

Basaltic magma which formed diorite are provided a lot of H_2O and SO_2 and vesiculated

From amphibole contained in diorite and tonalite

①The amphiboles recorded from early to late magma differentiation, and OZS in the pale-green rim which formed in subsolidus.
②$Fe/(Fe^{2+}+Fe^{3+})$ contained in the amphibole **decreases** from pale-brown core to pale-green rim.
→**Oxidation has progressed**, and Fe^{3+} have increased.
③Cl contained in the amphibole are **very little** (<0.03Wt%).

Discussion②

When OZS is formed, equilibrium temperature and pressure

Approach	Equilibrium temperature and pressure	Reference
Geothermometer by Ti	640℃～545℃	Otten, 1984[4]
Geobarometer by Al	1.7kbar～1.0kbar (1.7×10^6hPa～1.0×10^6hPa)	Mutch et al., 2016[5]
Geothermometer which utilizes plagioclase and alkali-feldspar	Under 400℃ (1kbar/1.0×10^6hPa) Under 500℃ (10kbar/1.0×10^7hPa)	Whitney and Stormer, 1977[6]
Fugacity of opaque minerals assembly	$\log fO_2 = -19.5$～-19.0 (550℃) $\log fS_2 = -3.5$～-2.5 (550℃)	Nedachi et al., 1984[7]

Conclusion

The result by using geothermometer and geobarometer indicated the OZS was formed at subsolidus.

Therefore, our report in 2024; the examination that OZS of amphibole was formed at subsolidus, was proved.

By outcrop survey of Australia and Southwest, OZS contained in the amphibole which turn out to be influenced by Hydrothermal residual are discovered in different ages and areas.

→OZS of amphibole in plutonic rocks have potential which is indicator to circulation of Hydrothermal residual liquid in subsolidus.

Future task

To demonstrate the validity of the OZS, would it be necessary to investigate all rock bases worldwide?

This is impossible.

To show OZS is international indicator…

Which region？

How much data？

Which age group？

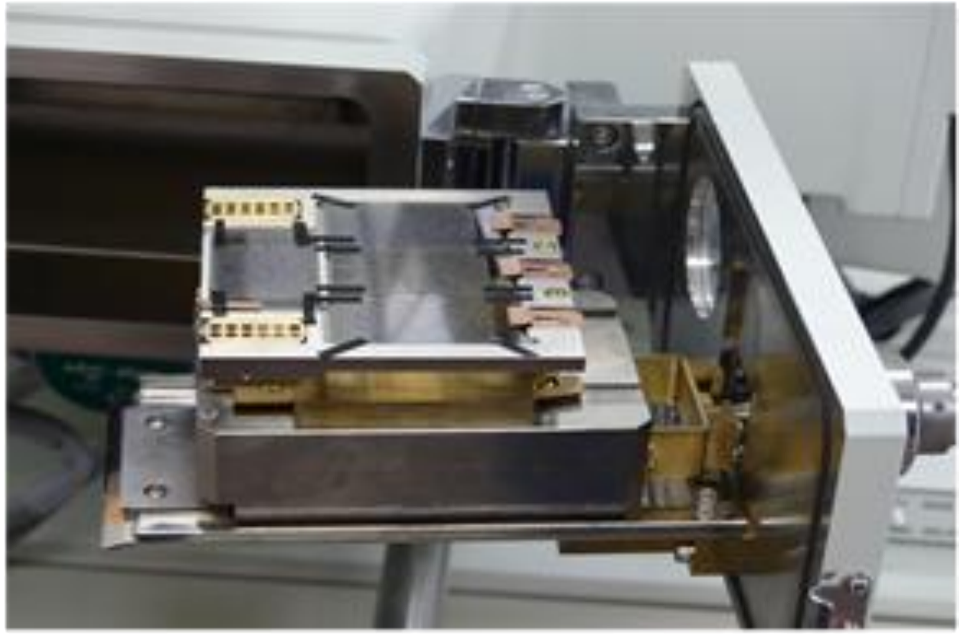
We will go to New Zealand in January

A series of plutonic rocks（from amphibole to pyroxene）

Acknowledgement

・We appriciate Professor Kawakami Tetsuo, Assistant Professor Higashino Fumiko and Master of Science student Hiroto Gondo (Department of Geology & Mineralogy, Graduate School of Science, Kyoto University) for their advice and assistance with EPMA analyses.

・We are grateful to Kazuya Kawakatsu, the Science Club advisor of our school for the valuable discussion.



Reference

1) Kawakatsu,K. and Yamaguchi,Y. (1987) Geochim.Cosmocim.Acta, 51,535-540.

2) Himeji Higashi High school Science Club, Hyogo Prefecture. (2023)
Japanese Geological Society 128th Jeneral meating/Kanagawa university.(in Japanese)

3) Himeji Higashi High school Science Club Geological society 131th Jeneral meating.(in Japanese)

4) Otten,M.T. (1984) Contrib.Mineral.Petrol,86, 189-199.

5) Mutch,E.J.F.,Blundy,J.D.,Tattitch,B.C.,Cooper,F.J. and Brooker,R.A. (2016)
Contrib.Mineral.Petrol, 171:85.

6) Whitney,J.A. and Stormer,J.C. (1977) Amer.Mineral.62, 687-691.

7) Munetomo Nedachi･Hitoshi Onuki･Takeyoshi Yoshida･Michio Tagiri. (1984)
Journal of Mineralogy, Petrology and Economic Geology. 79.,5.,200-213.(in Japanese)

Thank you for your attention.