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EGU General Assembly 2023

Supplementary materials

Mass transfer between serpentinites and metapelites in a paleo-subduction interface: a case study from the Yuli belt, eastern Taiwan

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Abstract

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Supplementary materials

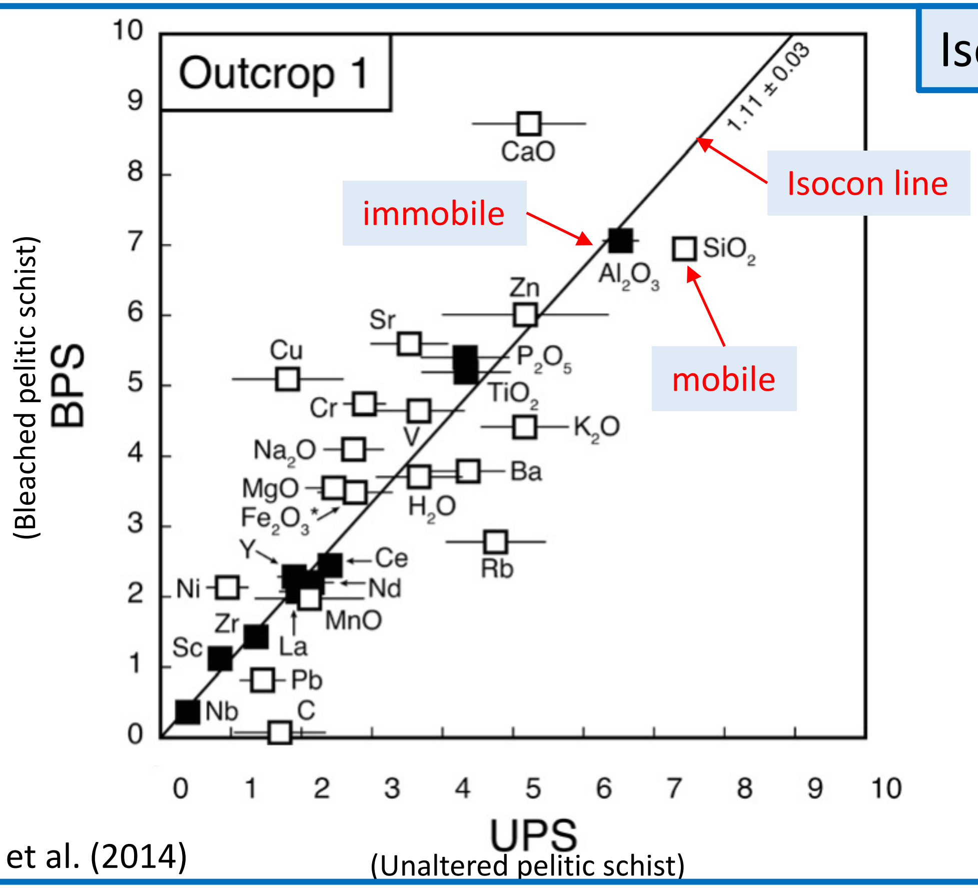
EGU General Assembly 2023

Introduction

Isocon method

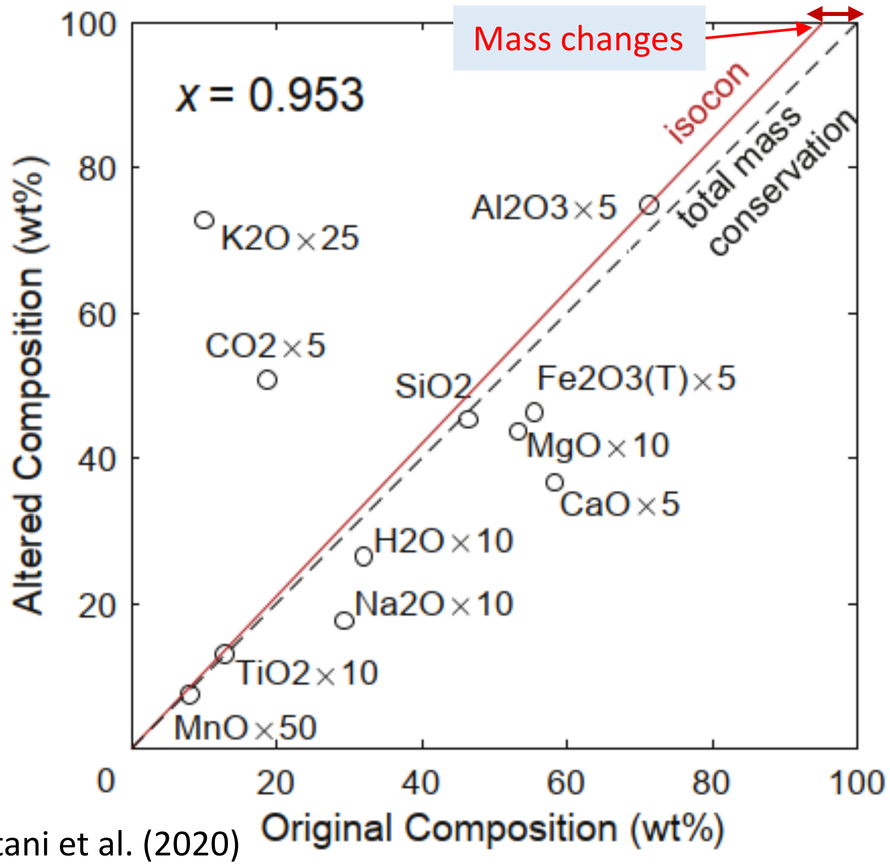
- **Isocon method** can be used to estimate the **mass, volume, or concentration changes** due to mass transfers during metasomatism.
- This method is calculated on the basis of **immobile element concentrations**.

(Grant, 1986; Grant, 2005; Mori et al., 2007; Kuwatani et al., 2020).



Mori et al. (2014)

Isocon method



Kuwatani et al. (2020)

Petrographic observations

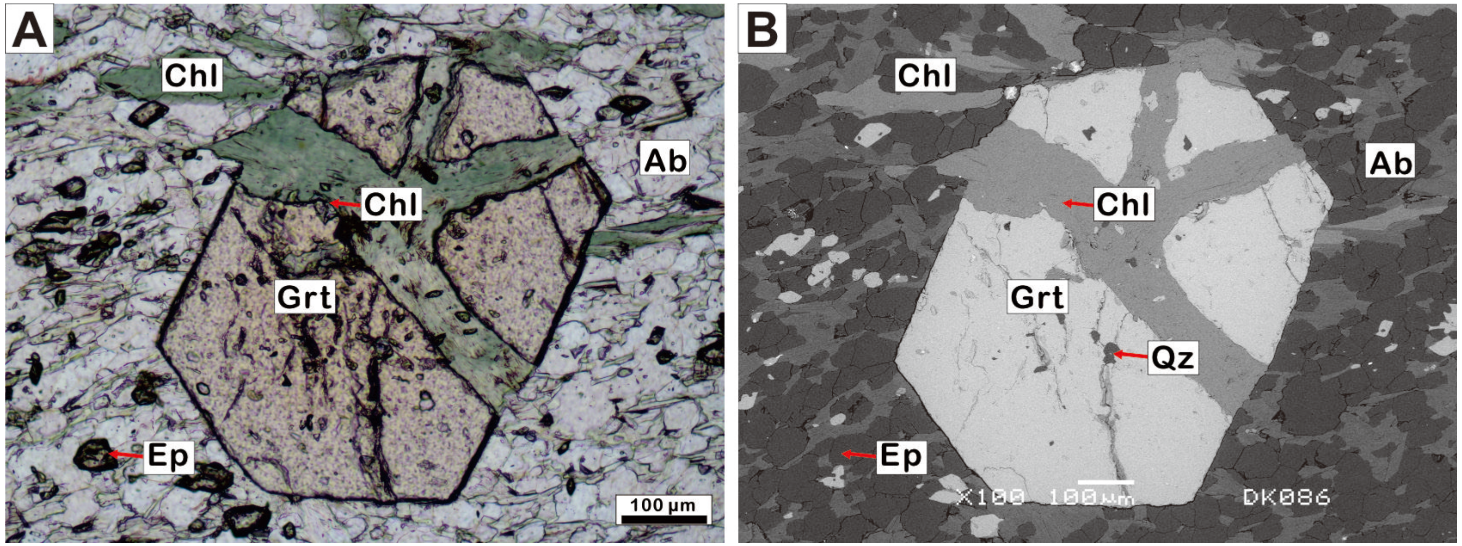
Metasomatic rocks at the Tsunkuanshan area

Zones		Rock names	Sample code	Texture	Petrology			Coordinate	
					Major minerals (90%)	Minor (≤9%)	Assesory (≤1%)	North	East
PS		Pelitic schist	PS001	Schistose	Ph, qz, chl, CM	Grt, ab, ttn, aln	Ap, zr, py, tour	23°29‘54.50"N	121°18‘20.99"E
			PS002	Schistose	Ph, ab, qz, CM	Grt, ttn, ilm	Ap, zr	-	-
			PS003	Schistose	Ph, qz, chl, CM	Grt, ab, ttn, aln	Ap, zr, py, tour	23°29‘26.49"N	121°18‘11.13"E
Metasomatic zones	Zone I	Chl-ab schist/rock	MZ101	Massive	Ab, chl	qz, ttn, ilm, ap, aln	Grt, py	23°29‘26.49"N	121°18‘11.13"E
			MZ102	Schistose	Ab, chl, ph	Grt, ttn, ilm, ep	Ap, aln, zr, py	23°29‘26.49"N	121°18‘11.13"E
			MZ103	Schistose	Ab, chl, ph	Ttn, ilm, ep, aln	Zr, py	23°29‘27.08"N	121°18‘10.75"E
	Zone II	Amp-ab rock	MZ201	Massive	Ab, chl, act, stp, qz	Ttn, rt, ilm, qz	Ap, py	23°29‘26.49"N	121°18‘11.13"E
			MZ202	Massive	Ab, brs, ttn	Ilm, aln, ep	Ap,zr, py	23°29‘27.08"N	121°18‘10.75"E
			MZ203	Massive	Ab, bio, gln	Ttn, ilm, ep	Ap, aln, zr, py	23°29‘27.08"N	121°18‘10.75"E
			MZ204	Massive	Ab, brs, ttn	Ilm, aln, ep	Ap,zr, py	23°29‘27.08"N	121°18‘10.75"E
	Zone I	Chl-ab rock	MZ104	Massive	Ab, chl, ep	Ttn, rt, ilm, aln	Ap, zr,py	23°29‘27.08"N	121°18‘10.75"E
	Zone III	Ab-chl schist	MZ301	Schistose	Chl (pse. grt/amp), ph, ep, ab	Ttn, aln	Ap, py	23°29‘26.49"N	121°18‘11.13"E
			MZ302	Schistose	Chl (pse. grt/amp), ph, ep	Ttn, aln	Ap, py	23°29‘26.49"N	121°18‘11.13"E
			MZ303	Schistose	Chl, ph, ab	Ttn, grt (pse), aln	Ap, zr, py	23°29‘27.08"N	121°18‘10.75"E
	Zone IV	Ep-chl schist	MZ401	Schistose	Ep, chl, ph	Ab, ttn	Ap, aln, zr, py	23°29‘27.08"N	121°18‘10.75"E
			MZ402	Schistose	Ep, chl, ab	Ttn, aln, ph	Ap, zr, py	23°29‘27.08"N	121°18‘10.75"E
			MZ403	Schistose	Ep, chl, ab	Ttn, ilm	Ap, zr	23°29‘27.08"N	121°18‘10.75"E
			MZ404	Schistose	Ep, chl, py	Tlc, ttn	Ilm, ap	23°29‘27.08"N	121°18‘10.75"E
	Zone V	Chl-tlc schist	MZ501	Schistose	Chl, tlc	Ep, ttn	Py, ap	23°29‘27.08"N	121°18‘10.75"E
			MZ502	Schistose	Chl, tlc	Py, ttn	Ap	23°29‘27.08"N	121°18‘10.75"E
			MZ503	Schistose	Tlc	Chl, mag	Py	23°29‘27.08"N	121°18‘10.75"E
SP		Serpentinite	SP001	Schistose	Atg, mag	Chl, chr, car	Cr-spl, Fe-chr	23°29‘26.49"N	121°18‘11.13"E
			SP002	Schistose	Atg, mag	Chl, chr, car	Cr-spl, Fe-chr	23°29‘26.49"N	121°18‘11.13"E
			SP003	Massive	Atg, mag	Brc, chr, car	Ol, Cr-spl, Fe-chr	23°29‘26.49"N	121°18‘11.13"E

*24 selected samples

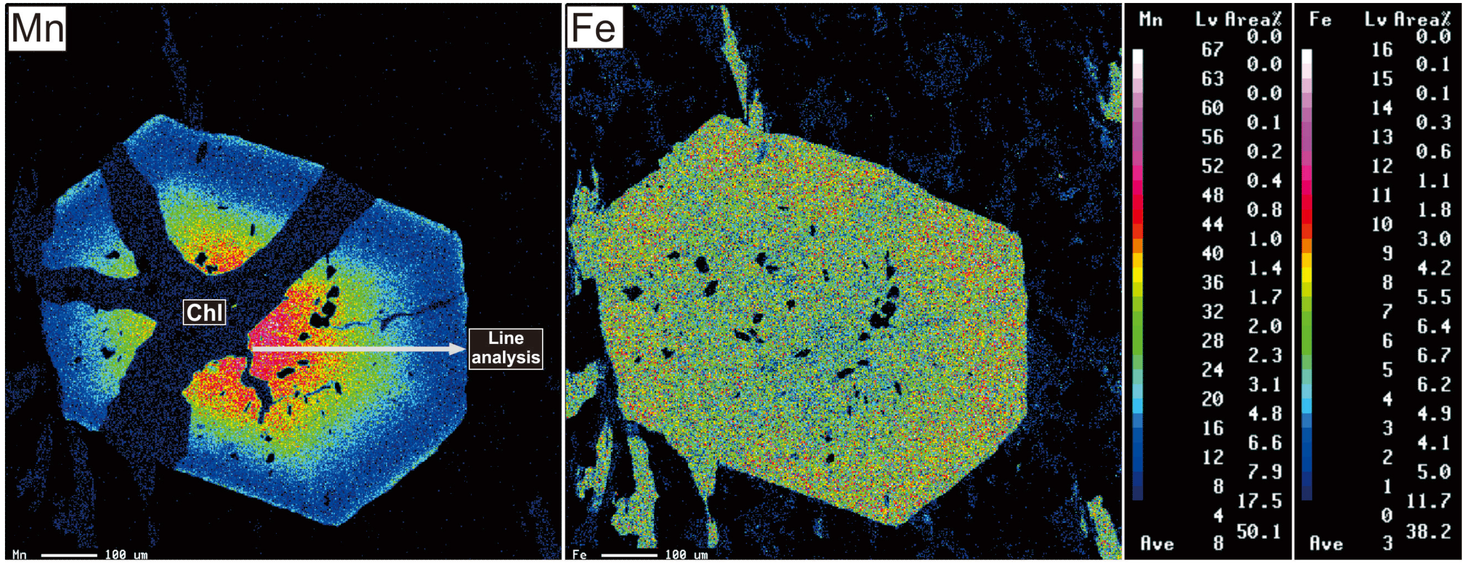
Petrographic observations and mineral compositions

Garnet from the zone I



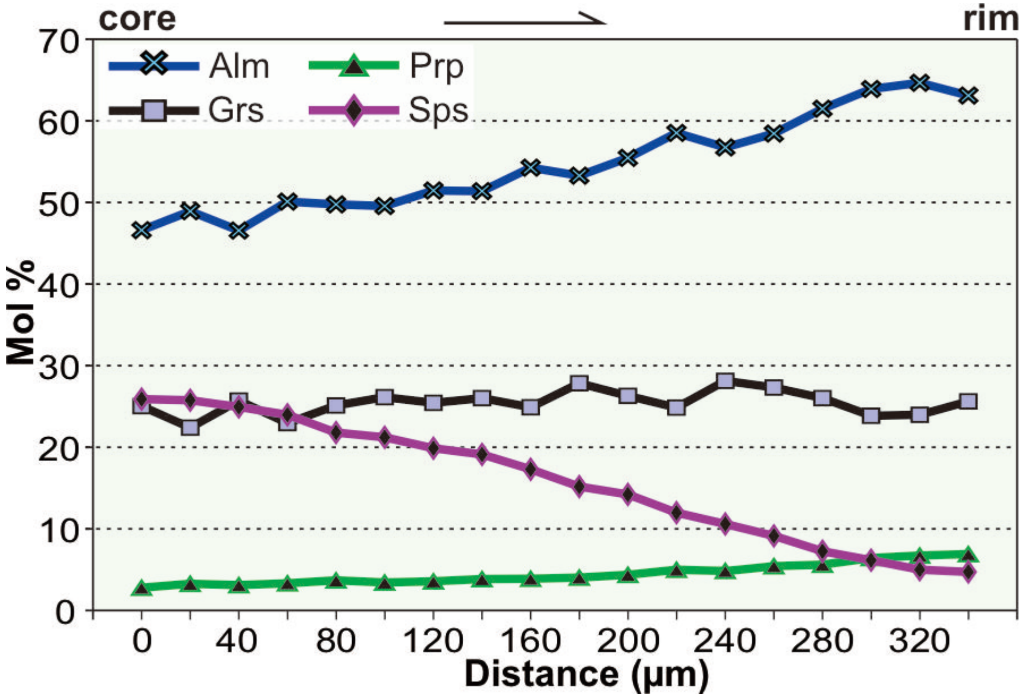
Garnet shows **prograde growth** during metamorphism (Enami, 1998)

EPMA elemental mapping



Zoned characteristics:

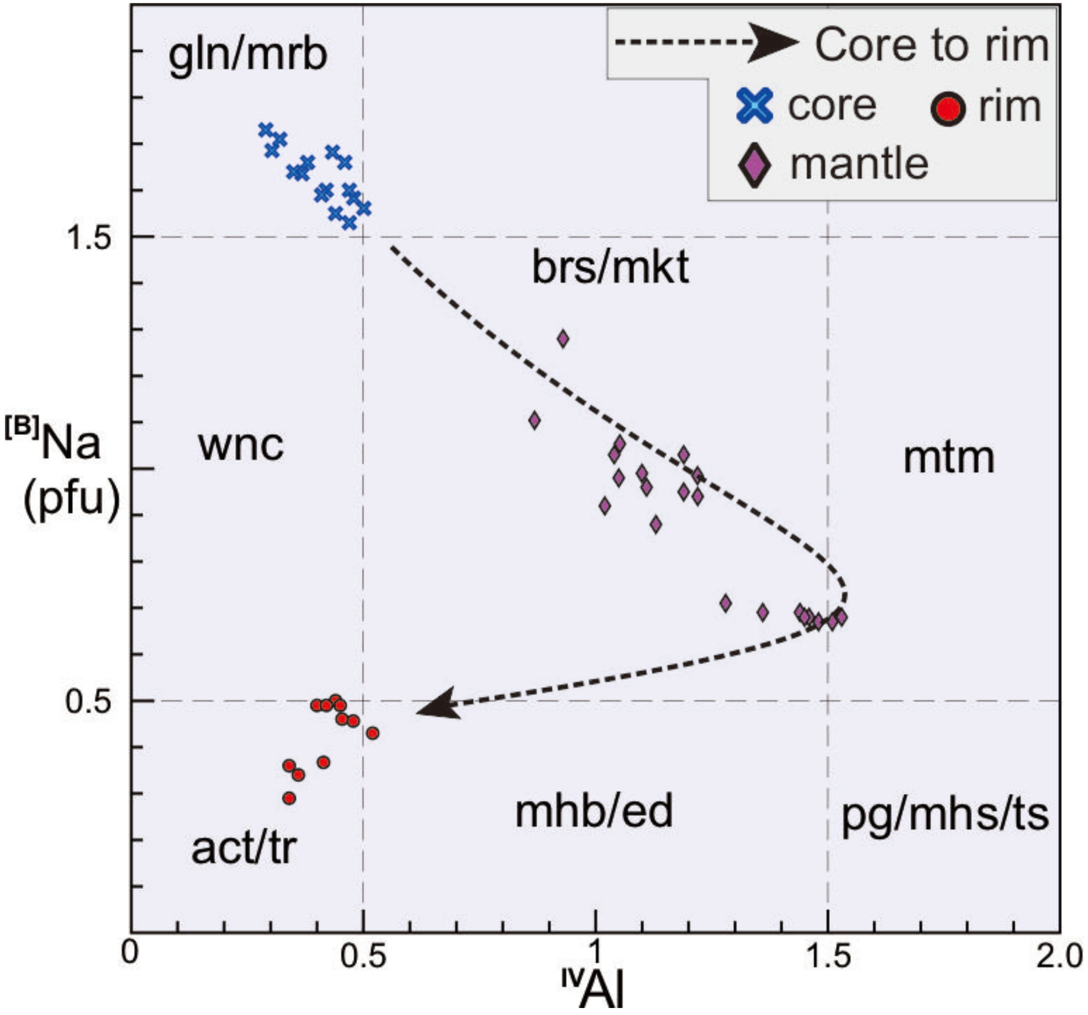
- **Increases of almandine**
- **Decreases of spessartine**

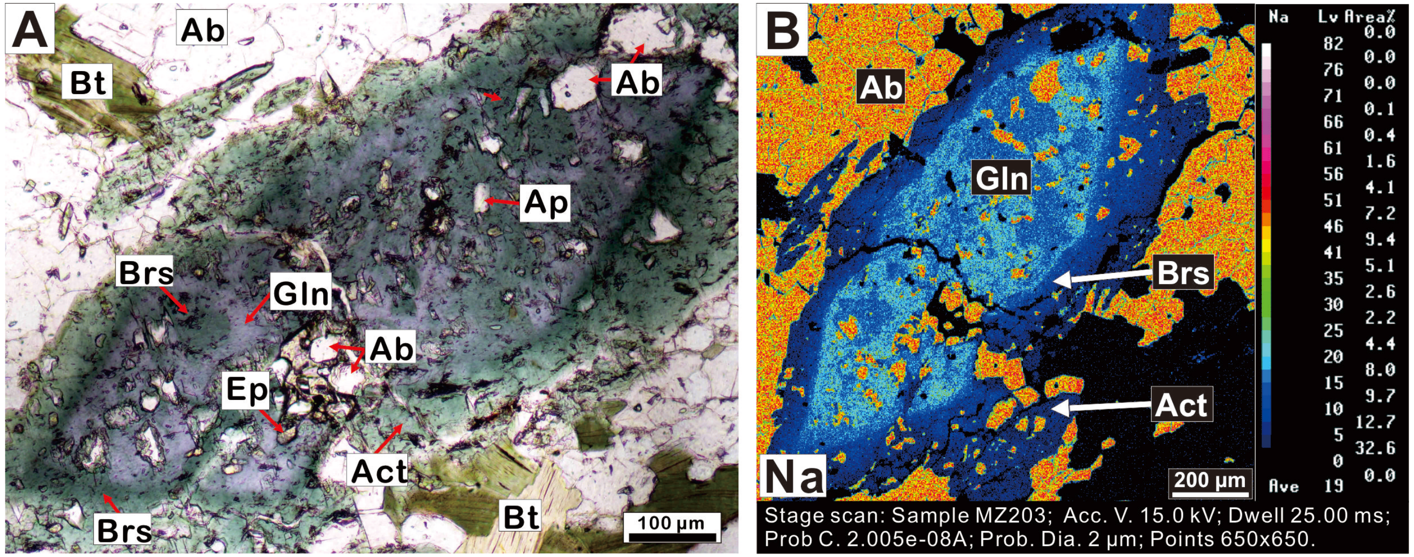


Petrographic observations and mineral compositions

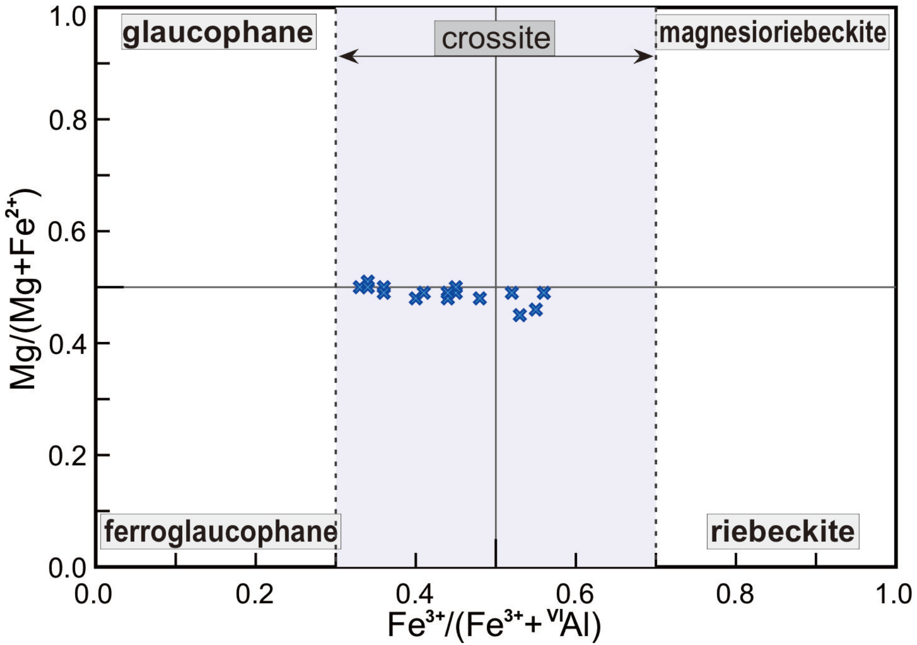
Amphibole in the zone II

Amphibole are zoned from **glaucophane** core, **barroisite** mantle, and **actinolite** rim.

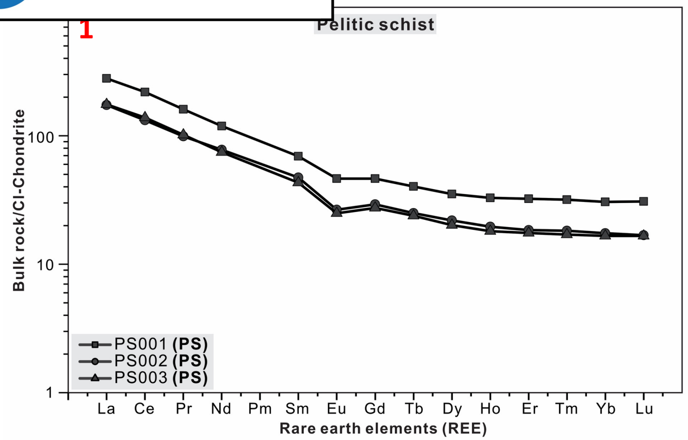


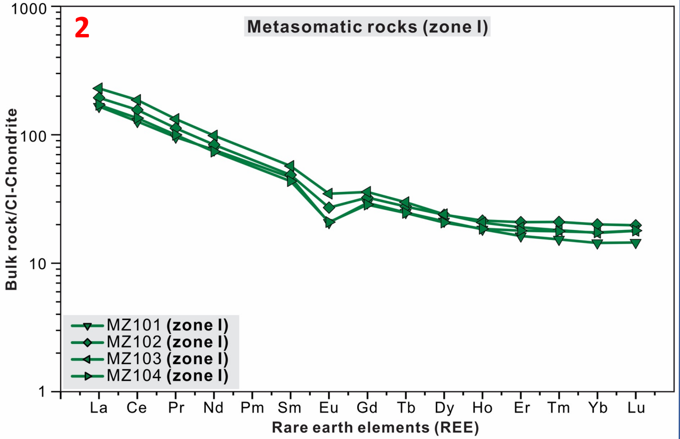


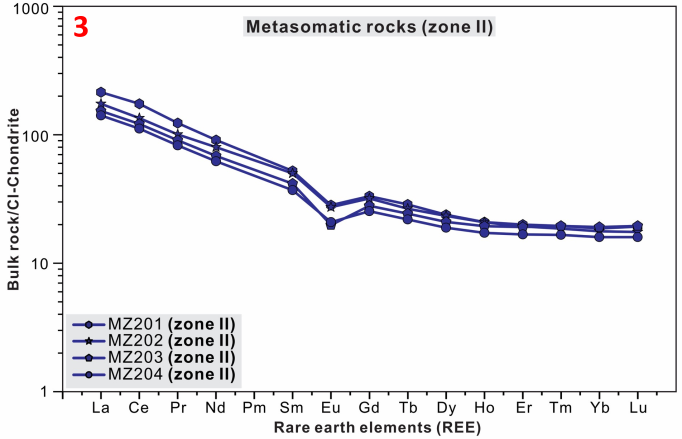
Glaucophane is a **high-pressure index mineral** which is an **indication** of **subduction zone metamorphism**

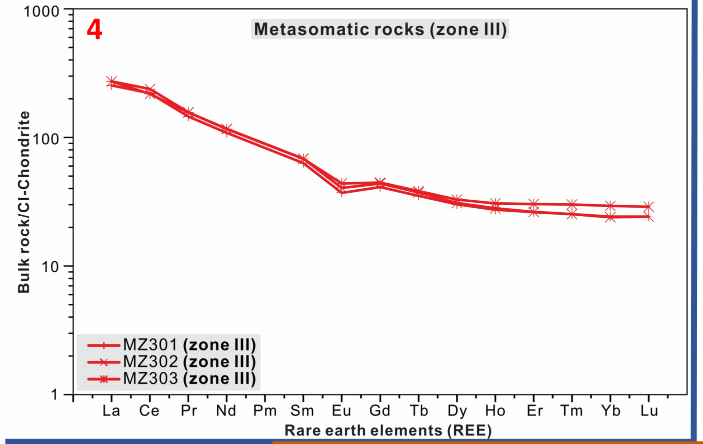


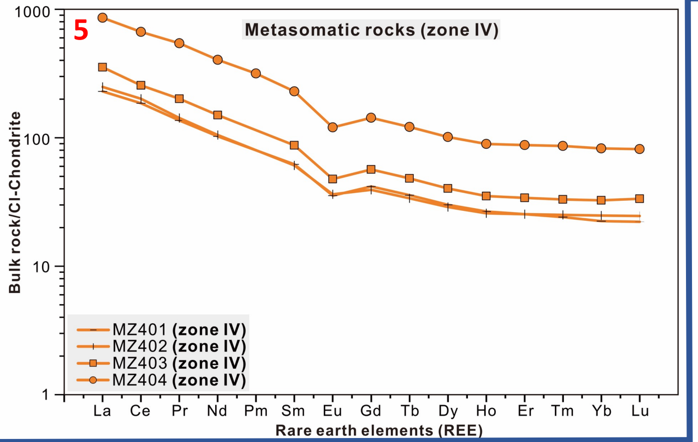
Whole-rock geochemical data







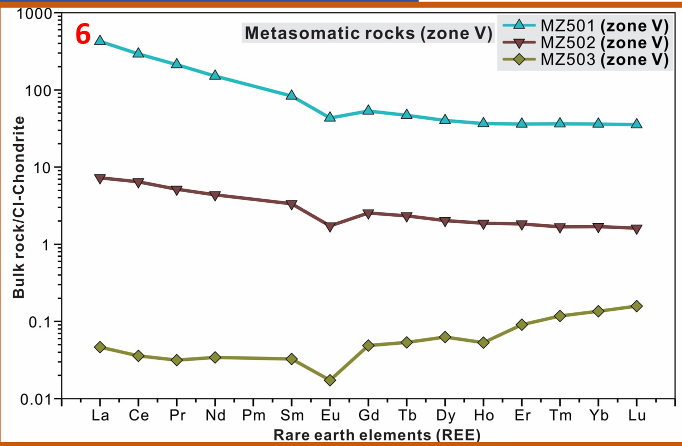


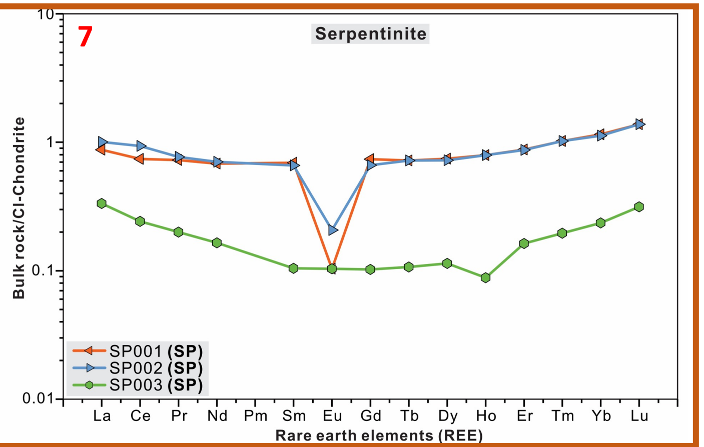


Rare earth elements (REE) compositions

- (Fig. 1 – 5) REE compositions in **pelitic schist** and **metasomatic rocks** (zone I, II, III, and IV) show **identical patterns.**

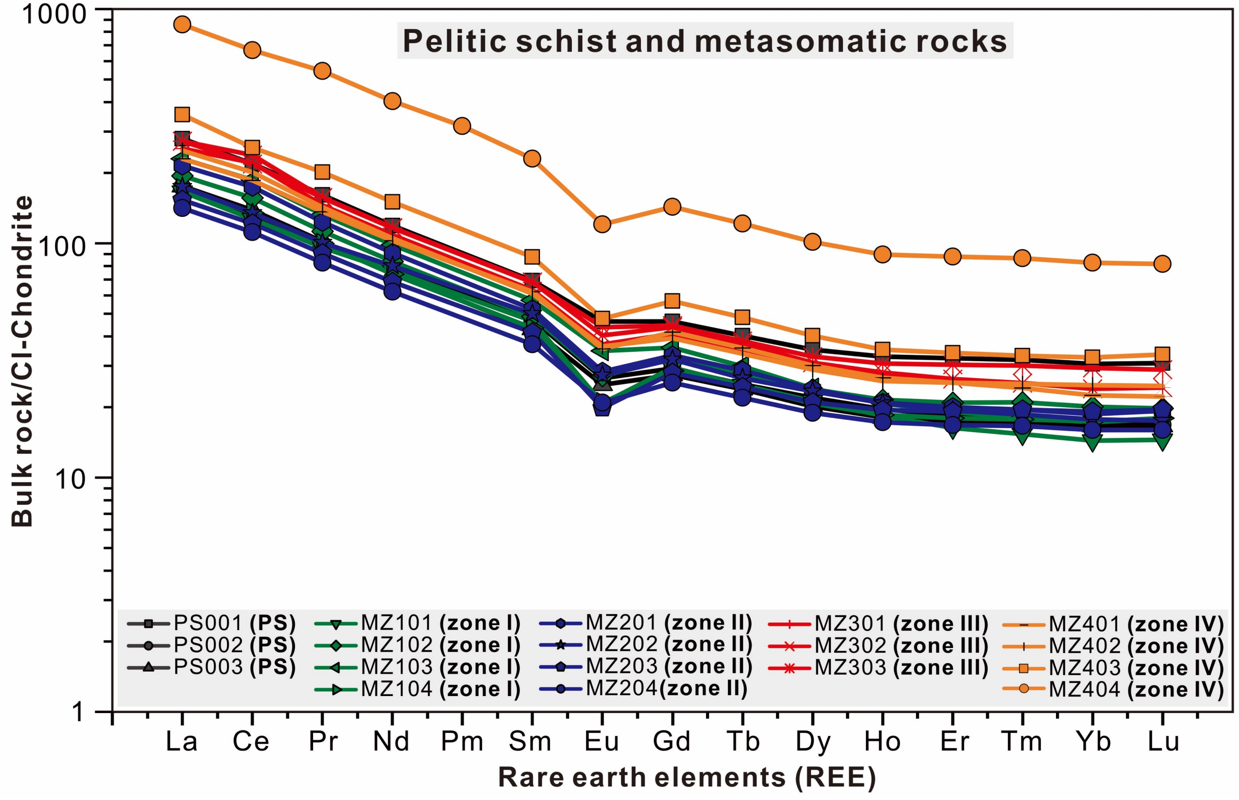
- (Fig. 6 – 7) REE patterns of **serpentinite** and **zone V** are scattered in their concentration ratios**.**
- Zone IV were likely highly affected by metasomatism.

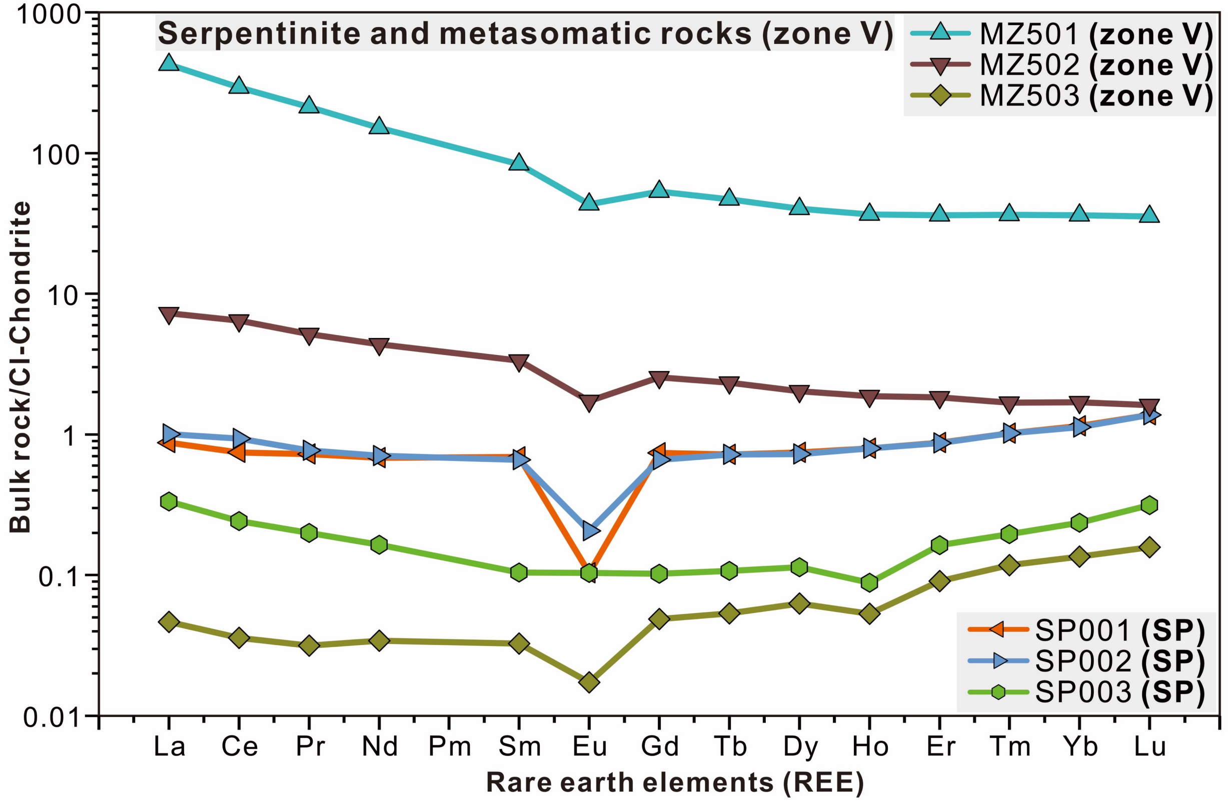




Whole-rock geochemical data

Comparison of REE compositions



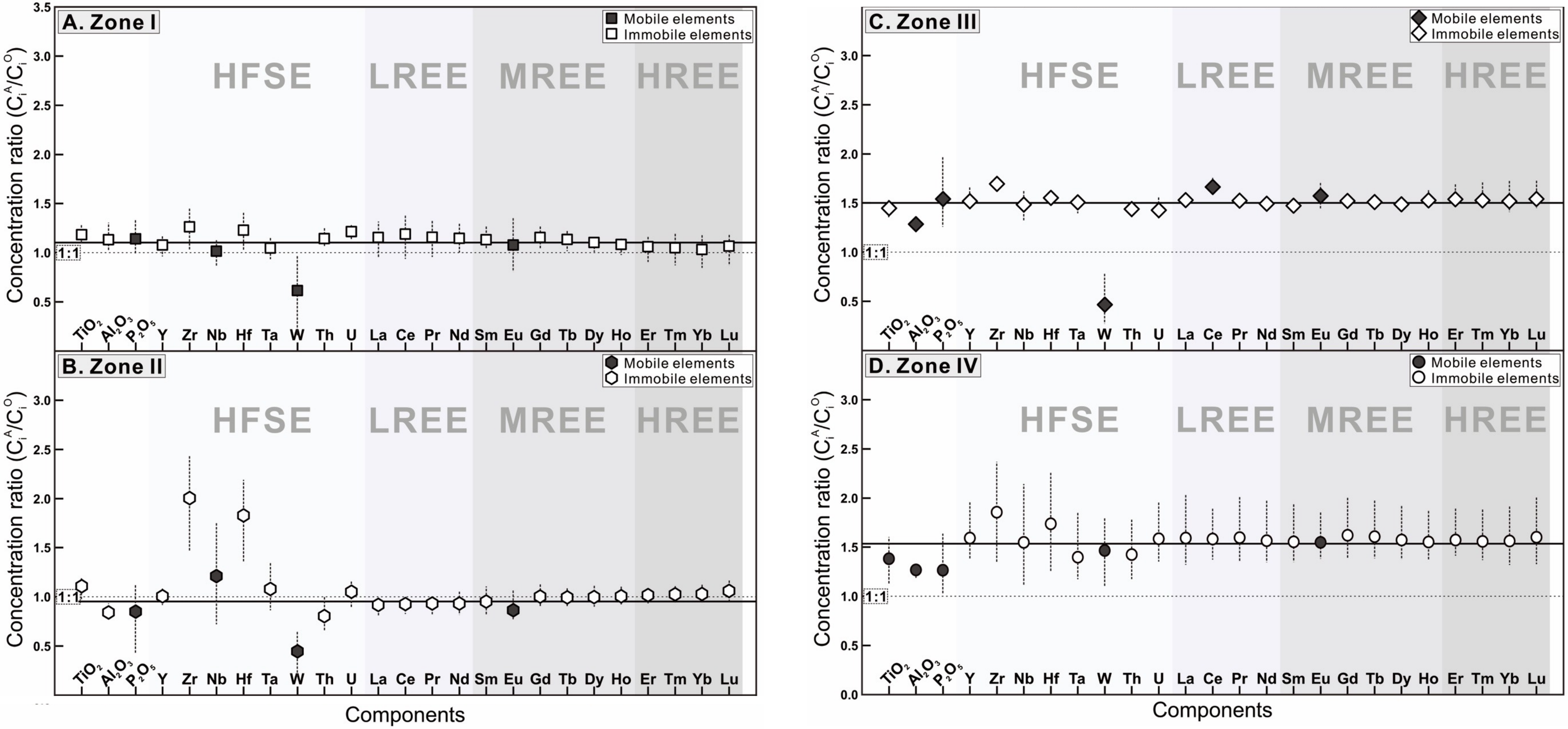


Metasomatic rocks (zone **I**, **II**, **III**, and **IV**) and **pelitic schist** were likely from the **same origin**

Isocon method can be used to estimate the **mass or concentration changed** within the metasomatic rocks.

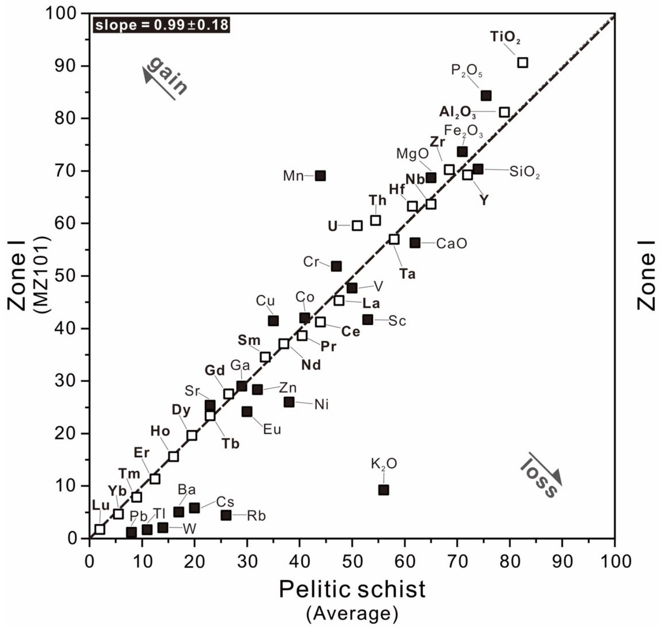
Element mobilities

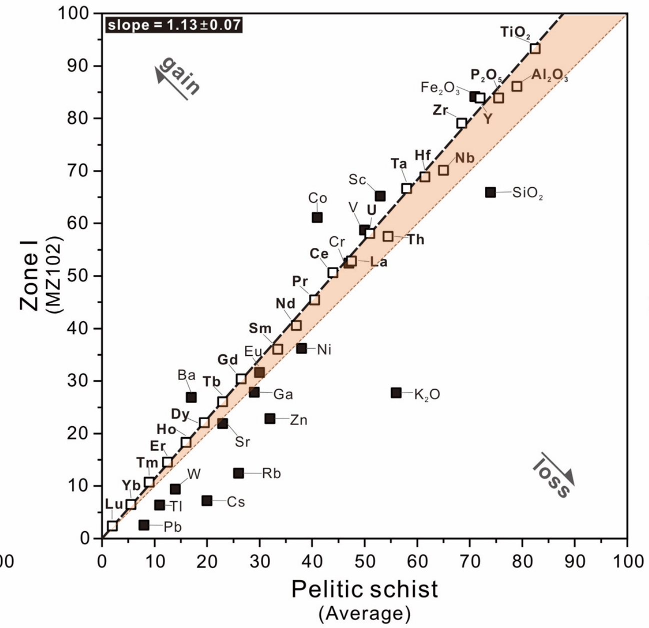
- Mobilities of components in the metasomatic zones over pelitic schist (average)
- C_i^a : component concentration of altered/metasomatic rocks
- C_i^o : component concentration of original rocks/pelitic schist

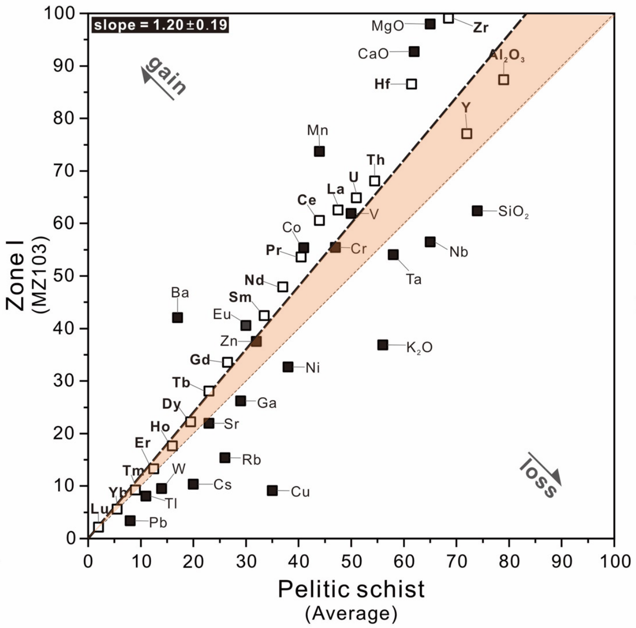


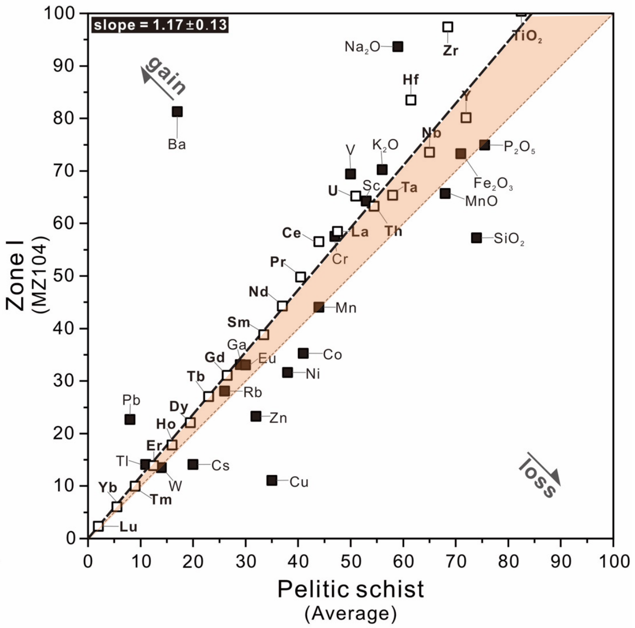
Isocon method (1)

Zone I









- Isocon slope **0.99 ± 0.10**
- Whole-rock mass **loss** about **1%**

- Immobile elements:

TiO_2, Al_2O_3, Y, Zr, Nb, Hf, Ta, Th, U, La, Ce, Pr, Nd, Sm, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu

- Isocon slope **1.13 ± 0.07**
- Whole-rock mass **gained** about **13%**

- Immobile elements:

TiO_2, Al_2O_3, P_2O_5, Y, Zr, Nb, Hf, Ta, Th, U, La, Ce, Pr, Nd, Sm, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu

- Isocon slope **1.20 ± 0.19**
- Whole-rock mass **gained** about **20%**

- Immobile elements:

TiO_2, Al_2O_3, P_2O_5, Y, Zr, Hf, Ta, Th, U, La, Ce, Pr, Nd, Sm, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu

- Isocon slope **1.17 ± 0.13**
- Whole-rock mass **gained** about **17%**

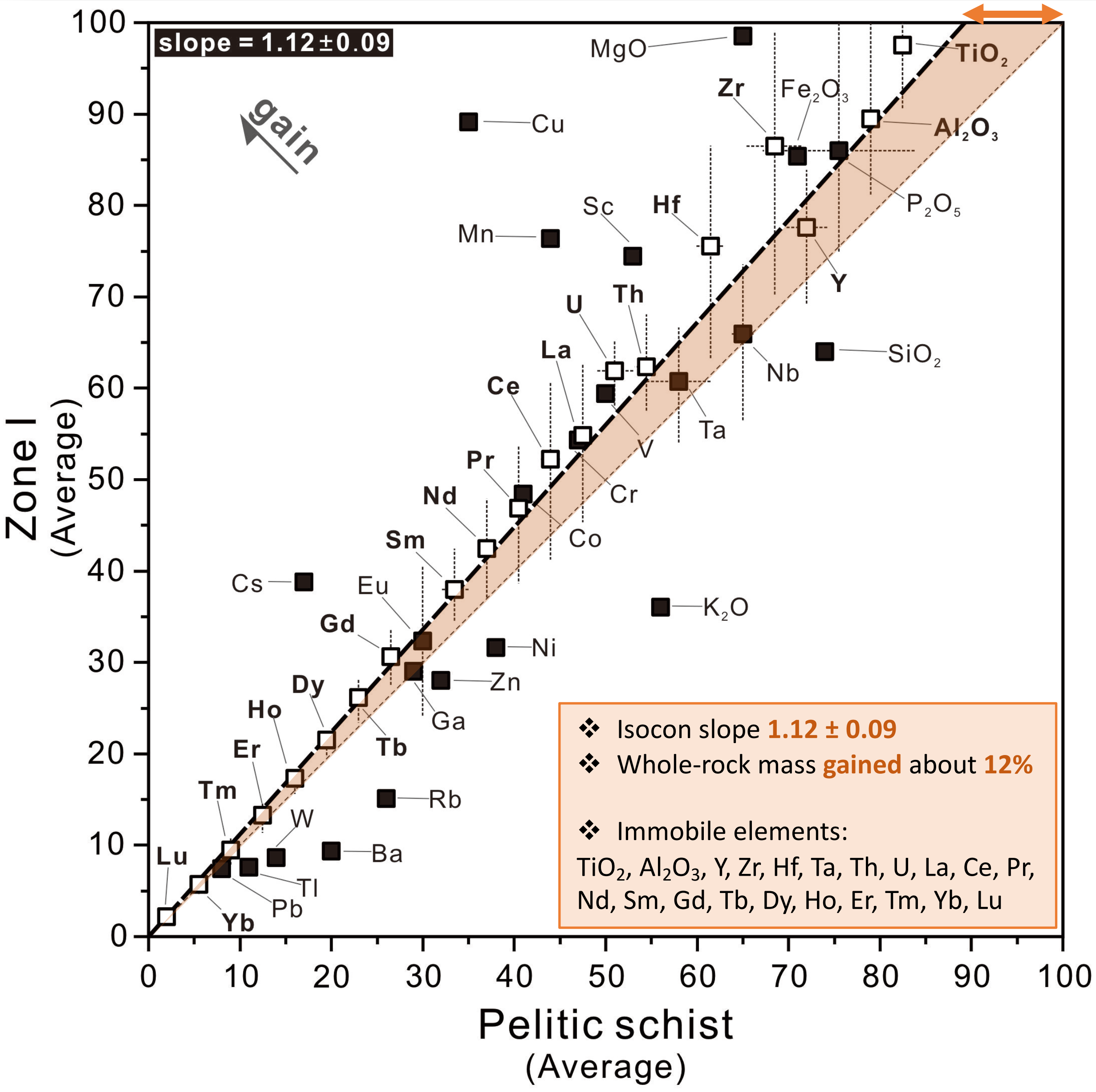
- Immobile elements:

TiO_2, Al_2O_3, Y, Zr, Nb, Hf, Ta, Th, U, La, Ce, Pr, Nd, Sm, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu

□ Immobile elements
■ Mobile elements

Isocon method (1)

Zone I (Average)



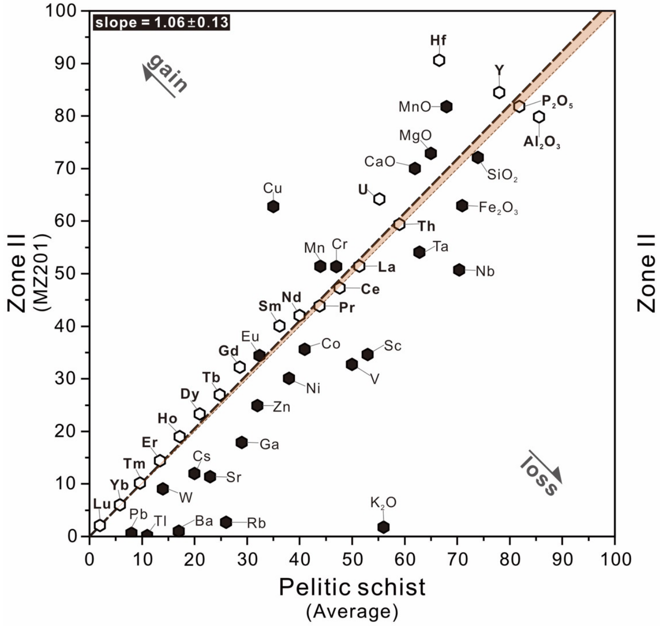
- Isocon slope **1.12 ± 0.09**
- Whole-rock mass **gained** about **12%**
- Immobile elements:

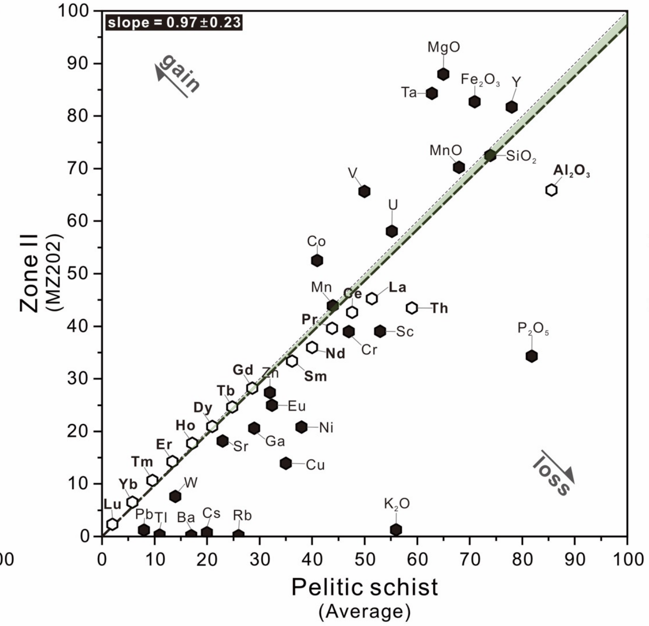
TiO_2, Al_2O_3, Y, Zr, Hf, Ta, Th, U, La, Ce, Pr, Nd, Sm, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu

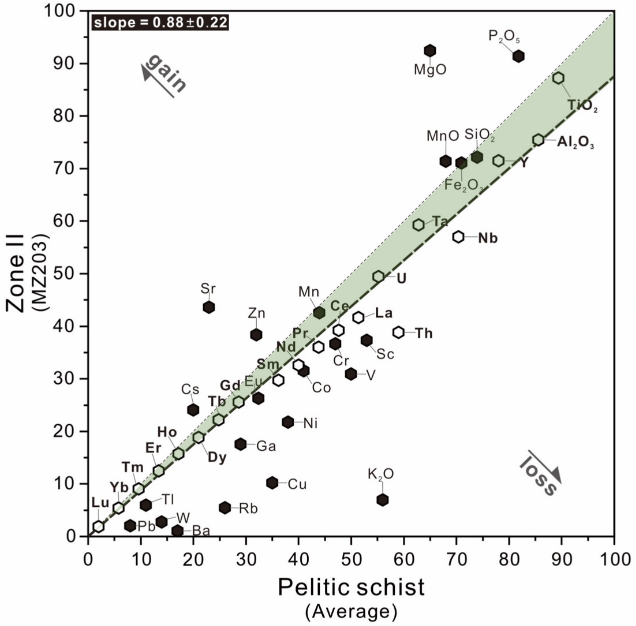
□ Immobile elements
■ Mobile elements

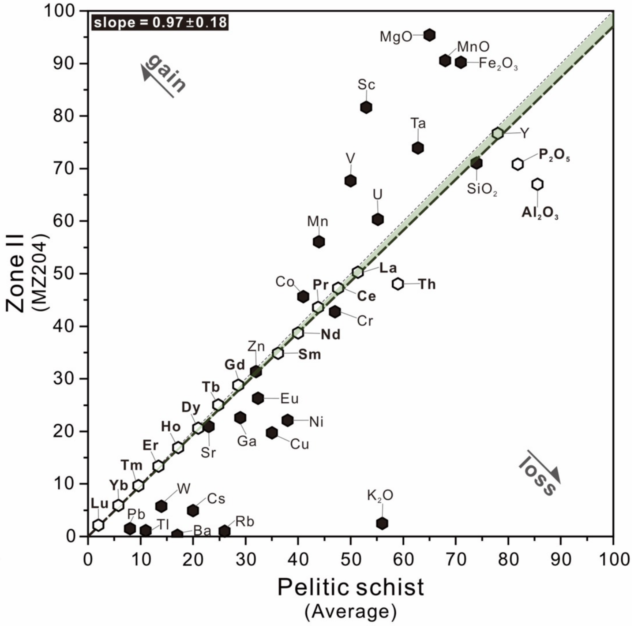
Isocon method (2)

Zone II









- Isocon slope **1.06 ± 0.13**
- Whole-rock mass **gained** about **6%**

- Immobile elements:

TiO_2, Al_2O_3, P_2O_5, Y, Zr, Hf, Th, U, La, Ce, Pr, Nd, Sm, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu

- Isocon slope **0.97 ± 0.23**
- Whole-rock mass **loss** about **3%**

- Immobile elements:

Al_2O_3, Zr, Hf, Th, La, Ce, Pr, Nd, Sm, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu

- Isocon slope **0.88 ± 0.22**
- Whole-rock mass **loss** about **12%**

- Immobile elements:

TiO_2, Al_2O_3, Y, Zr, Nb, Hf, Ta, Th, U, La, Ce, Pr, Nd, Sm, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu

- Isocon slope **0.97 ± 0.18**
- Whole-rock mass **loss** about **3%**

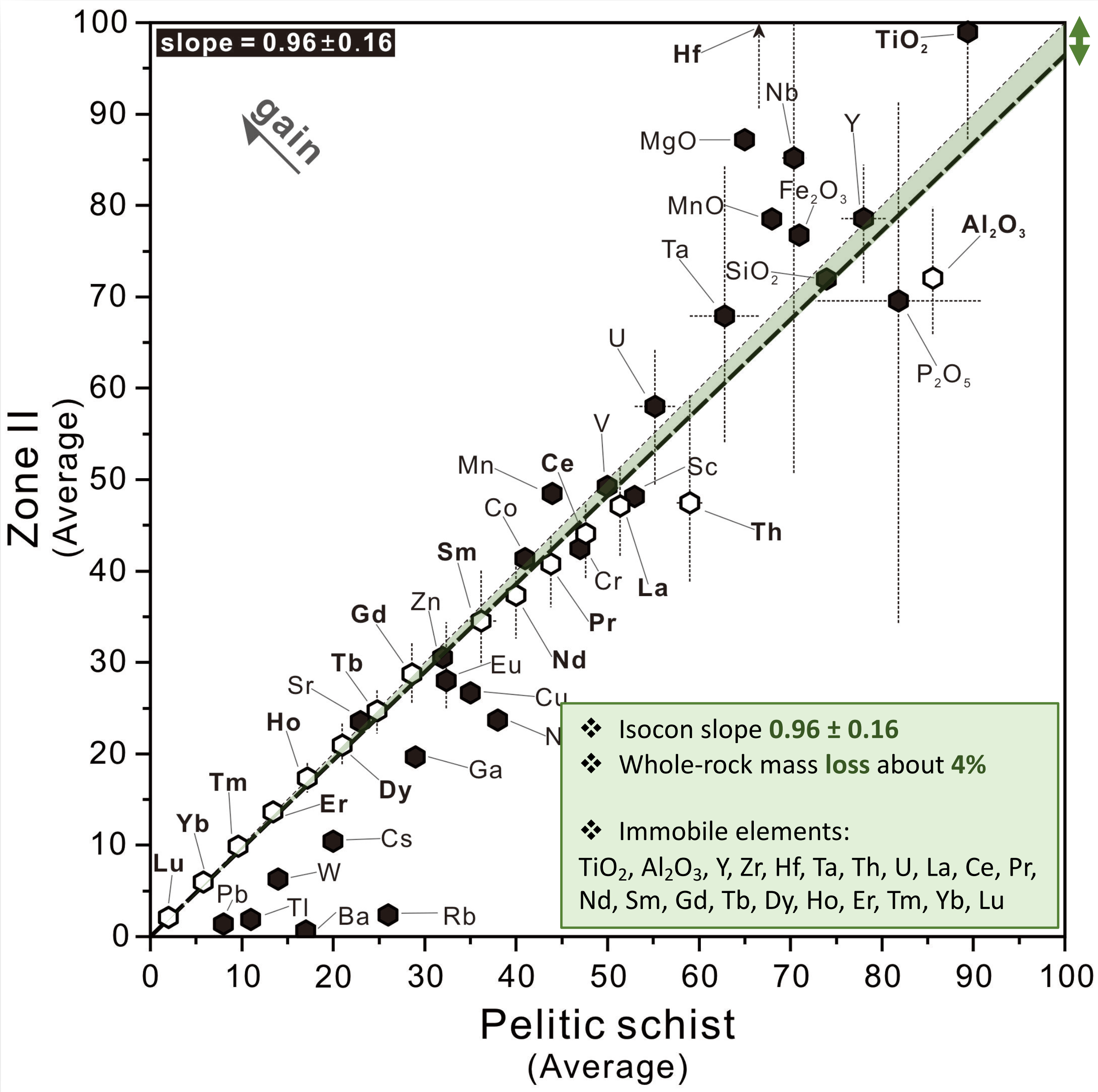
- Immobile elements:

Al_2O_3, P_2O_5, Y, Zr, Hf, Th, La, Ce, Pr, Nd, Sm, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu

⬡ Immobile elements
⬢ Mobile elements

Isocon method (2)

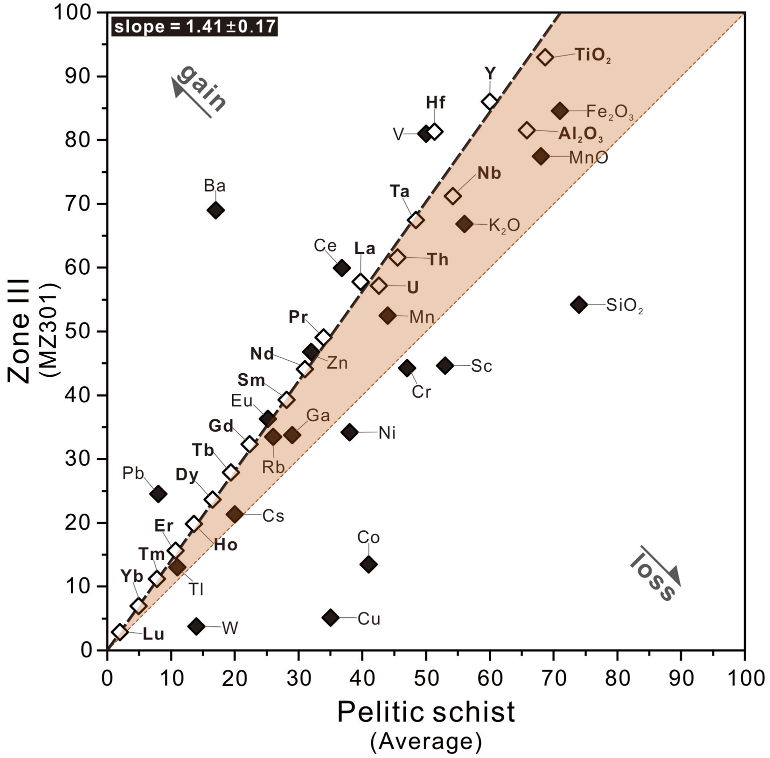
Zone II (average)

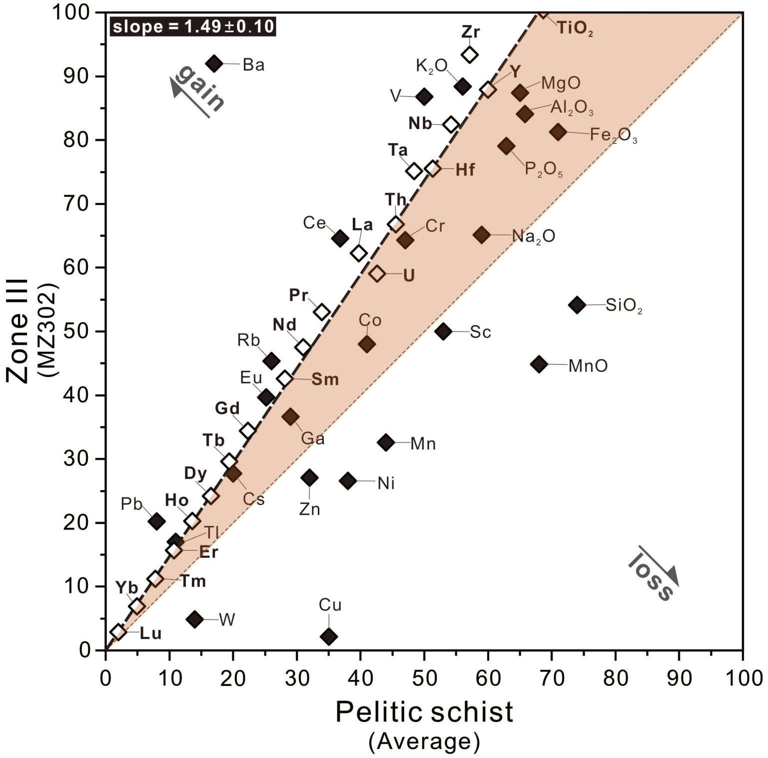


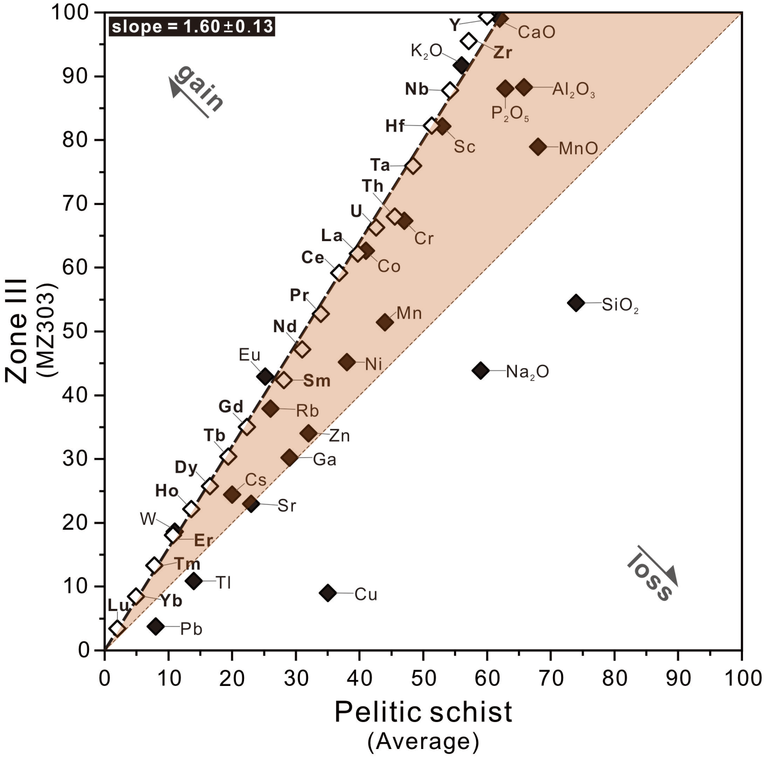
⬡ Immobile elements
⬢ Mobile elements

Isocon method (3)

Zone III







- Isocon slope **1.41 ± 0.17**
- Whole-rock mass **gained** about **41%**

- Immobile elements:

TiO_2, Al_2O_3, Y, Zr, Nb, Hf, Ta, Th, U, La, Pr, Nd, Sm, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu

- Isocon slope **1.49 ± 0.10**
- Whole-rock mass **gained** about **49%**

- Immobile elements:

TiO_2, Y, Zr, Nb, Hf, Ta, Th, U, La, Pr, Nd, Sm, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu

- Isocon slope **1.60 ± 0.13**
- Whole-rock mass **gained** about **60%**

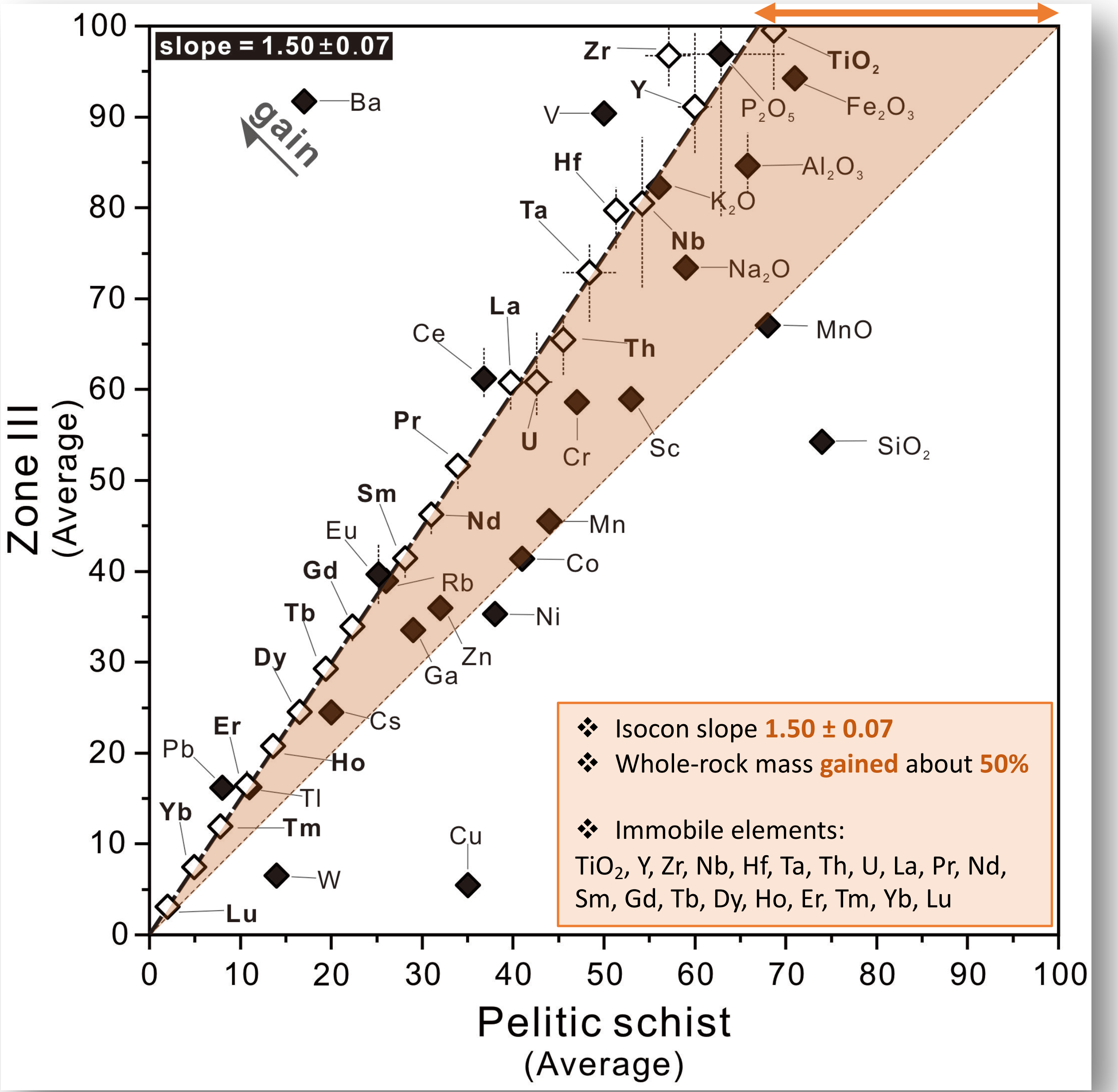
- Immobile elements:

TiO_2, Y, Zr, Nb, Hf, Ta, Th, U, La, Ce, Pr, Nd, Sm, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu

◇ Immobile elements
◆ Mobile elements

Isocon method (3)

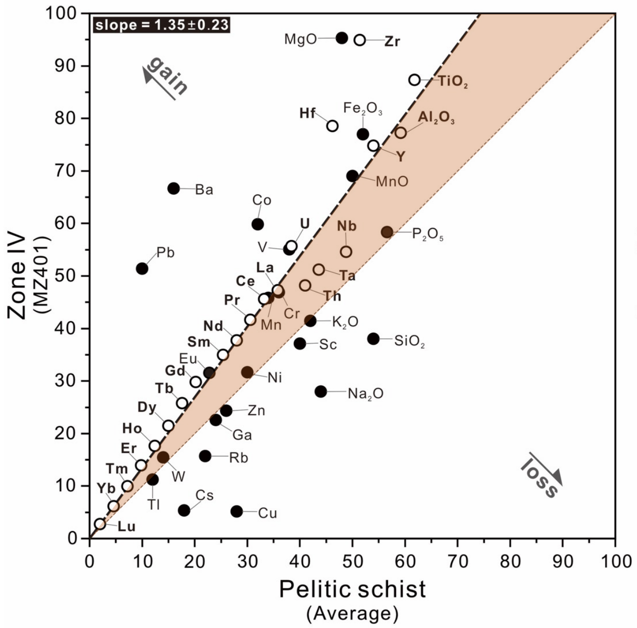
Zone III (average)

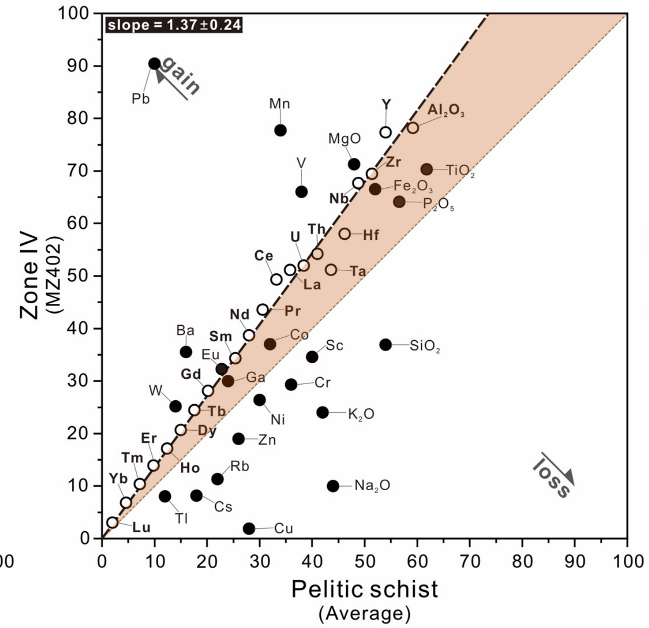


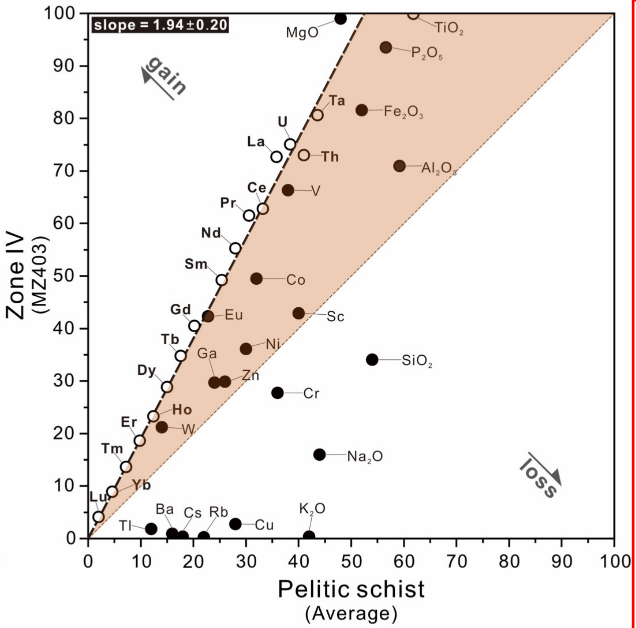
◇ Immobile elements
◆ Mobile elements

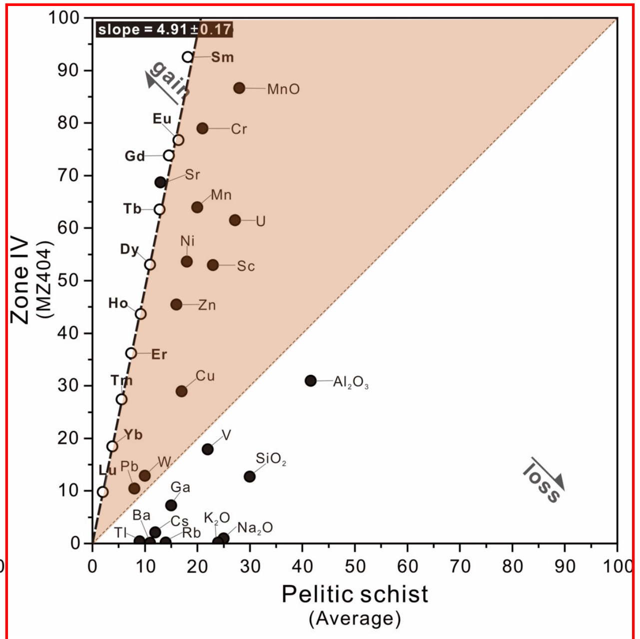
Isocon method (4)

Zone IV









❖ Isocon slope **1.35 ± 0.23**

❖ Whole-rock mass **gained** about **35%**

❖ Immobile elements:
TiO_2, Al_2O_3, Y, Zr, Nb, Hf, Ta, Th, U, La, Ce, Pr, Nd, Sm, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu

❖ Isocon slope **1.37 ± 0.24**

❖ Whole-rock mass **gained** about **37%**

❖ Immobile elements:
Al_2O_3, P_2O_5, Y, Zr, Nb, Hf, Ta, Th, U, La, Ce, Pr, Nd, Sm, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu

❖ Isocon slope **1.94 ± 0.20**

❖ Whole-rock mass **gained** about **94%**

❖ Immobile elements:
Y, Zr, Nb, Hf, Ta, Th, U, La, Ce, Pr, Nd, Sm, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu

❖ Isocon slope **4.91 ± 0.17**

❖ Whole-rock mass **gained** about **391%**

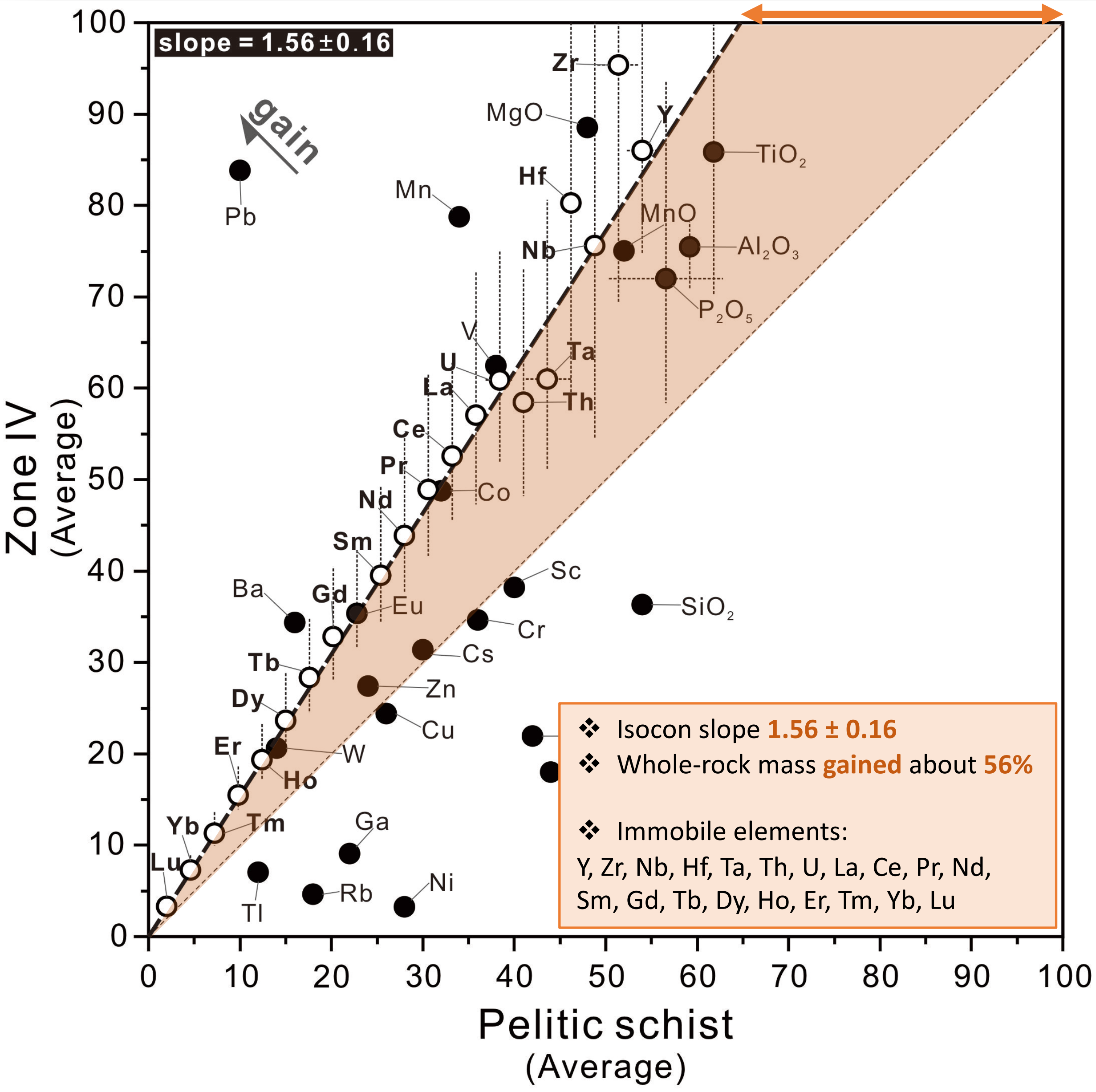
❖ Immobile elements:
TiO_2, Y, Zr, Nb, Hf, Ta, Th, La, Ce, Sm, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu

This sample is **excluded** from the **gain** or **loss** calculation because it is likely to have been highly affected by metasomatism than other samples.

○ Immobile elements
● Mobile elements

Isocon method (4)

Zone IV (average)

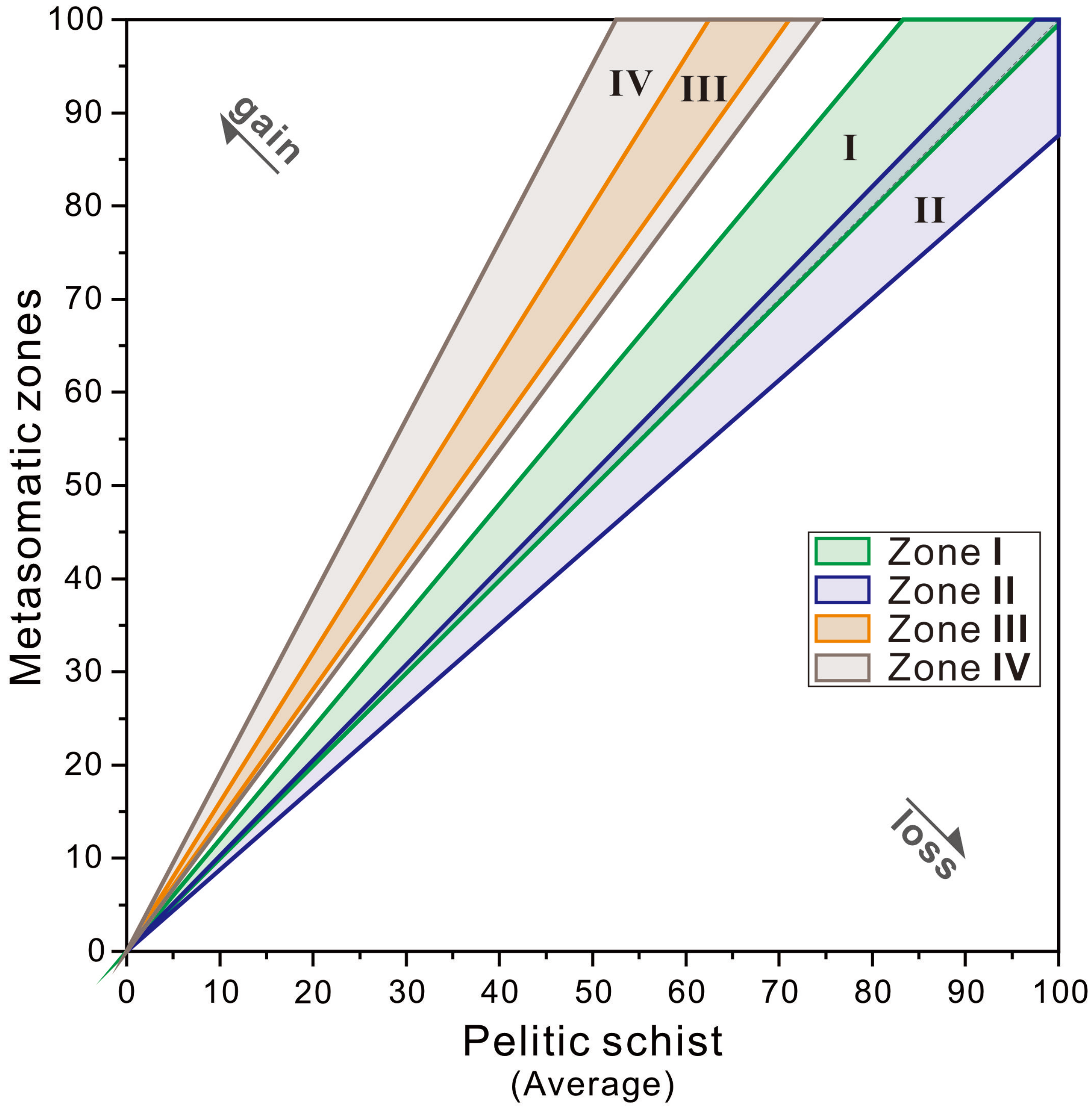


- Isocon slope **1.56 ± 0.16**
- Whole-rock mass **gained** about **56%**
- Immobile elements:

Y, Zr, Nb, Hf, Ta, Th, U, La, Ce, Pr, Nd, Sm, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu

○ Immobile elements
● Mobile elements

Isocon method (5)



Comparison of whole-rock mass changes

- Zone **I, III, and IV** show **mass gained**
- Zone **II** displays **mass loss**

Mass changes

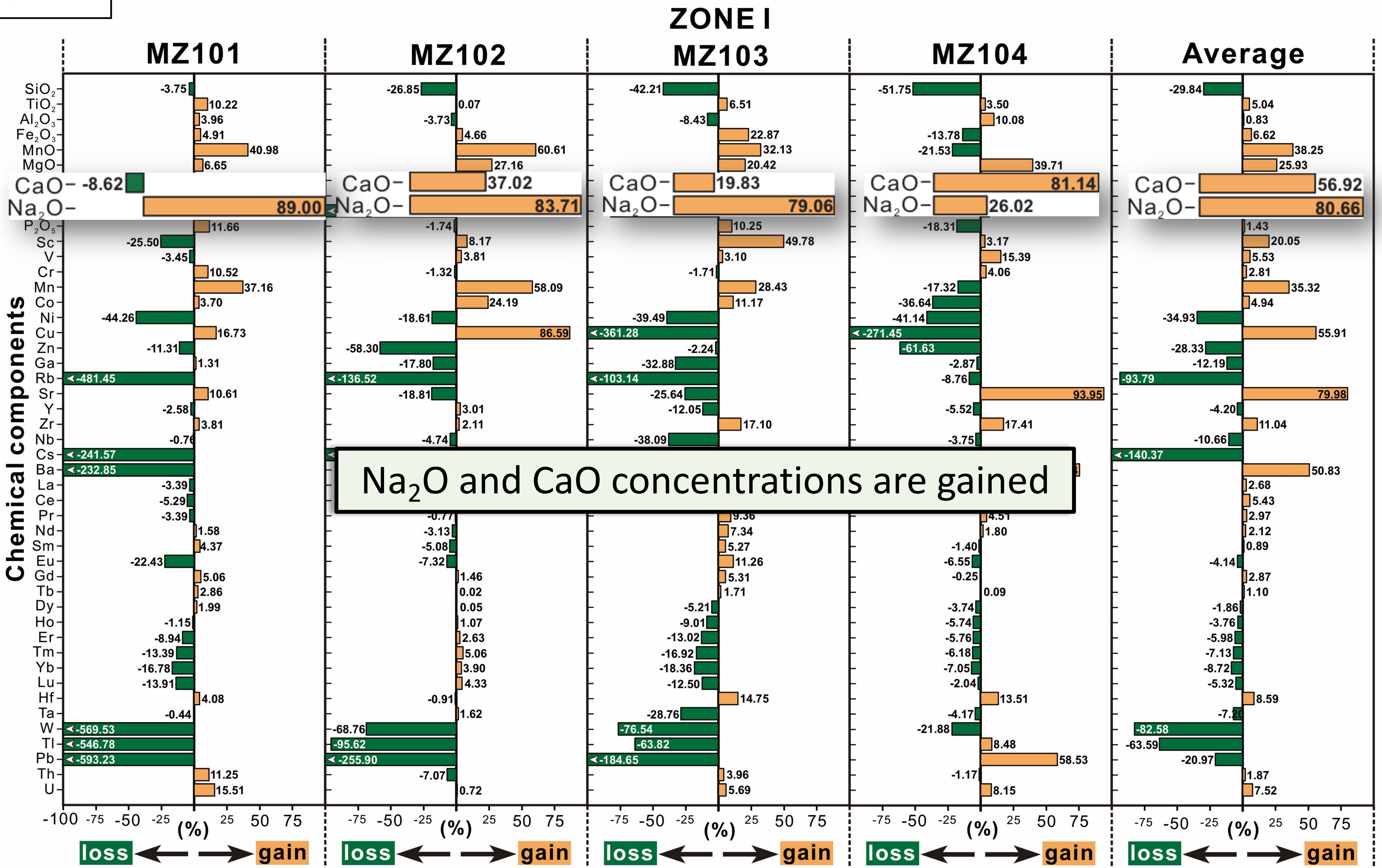
- Zone I: **-1%** to **+20%**
- Zone II: **-12%** to **+6%**
- Zone III: **+41%** to **+60%**
- Zone IV: **+35%** to **+94%**

average

Zones	Isocon slope	Mass changed
I	**1.12 ± 0.09**	**~12%** gained
II	**0.96 ± 0.16**	**~4%** loss
III	**1.50 ± 0.07**	**~50%** gained
IV	**1.56 ± 0.16**	**~56%** gained

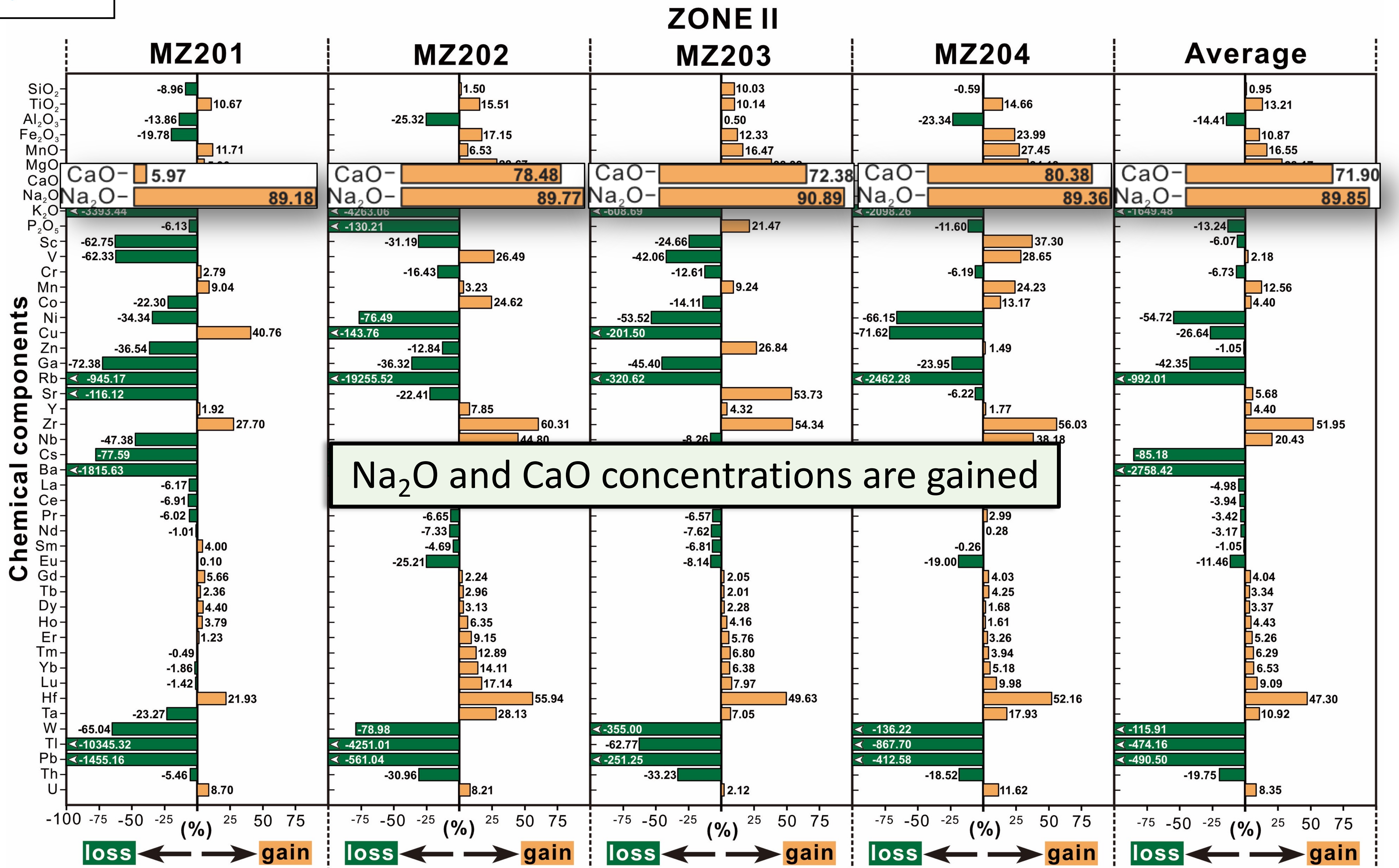
Metasomatism intensities are likely **increased** from the **zone I** to **zone IV.**

Gain or loss of component concentrations in the zone I



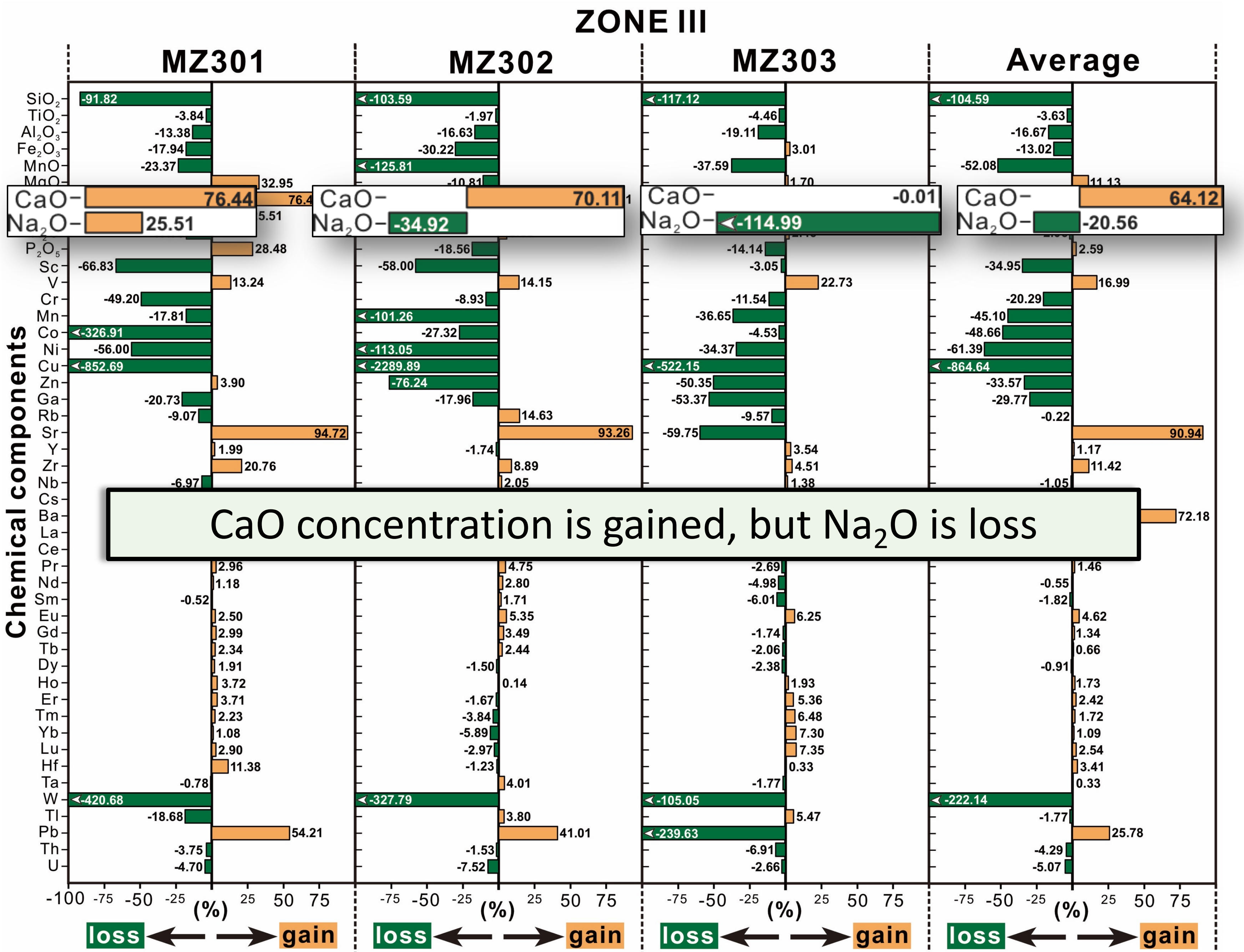
Na_2O and CaO concentrations are gained

Gain or loss of component concentrations in the zone II



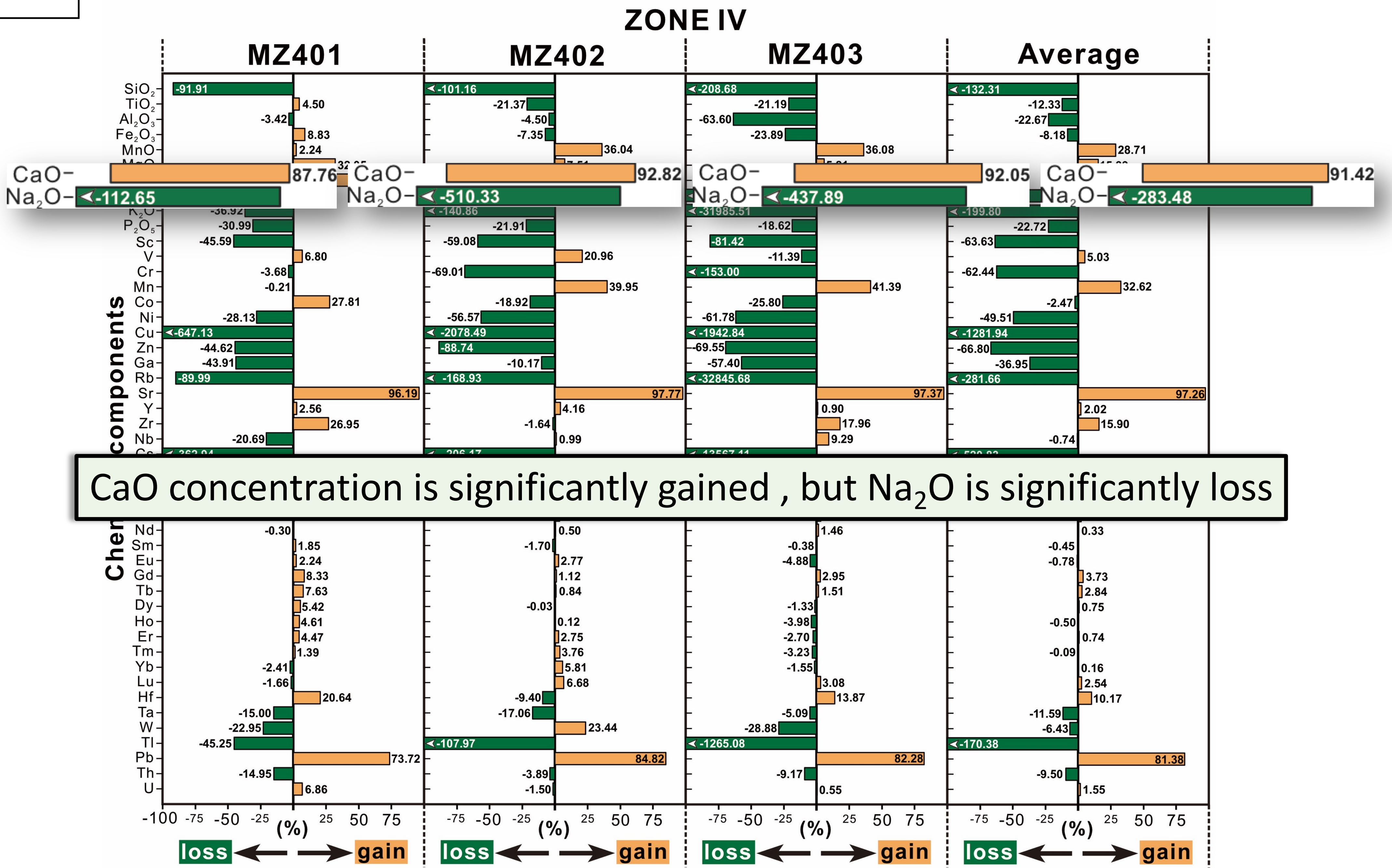
Na$_2$O and CaO concentrations are gained

Gain or loss of component concentrations in the zone III

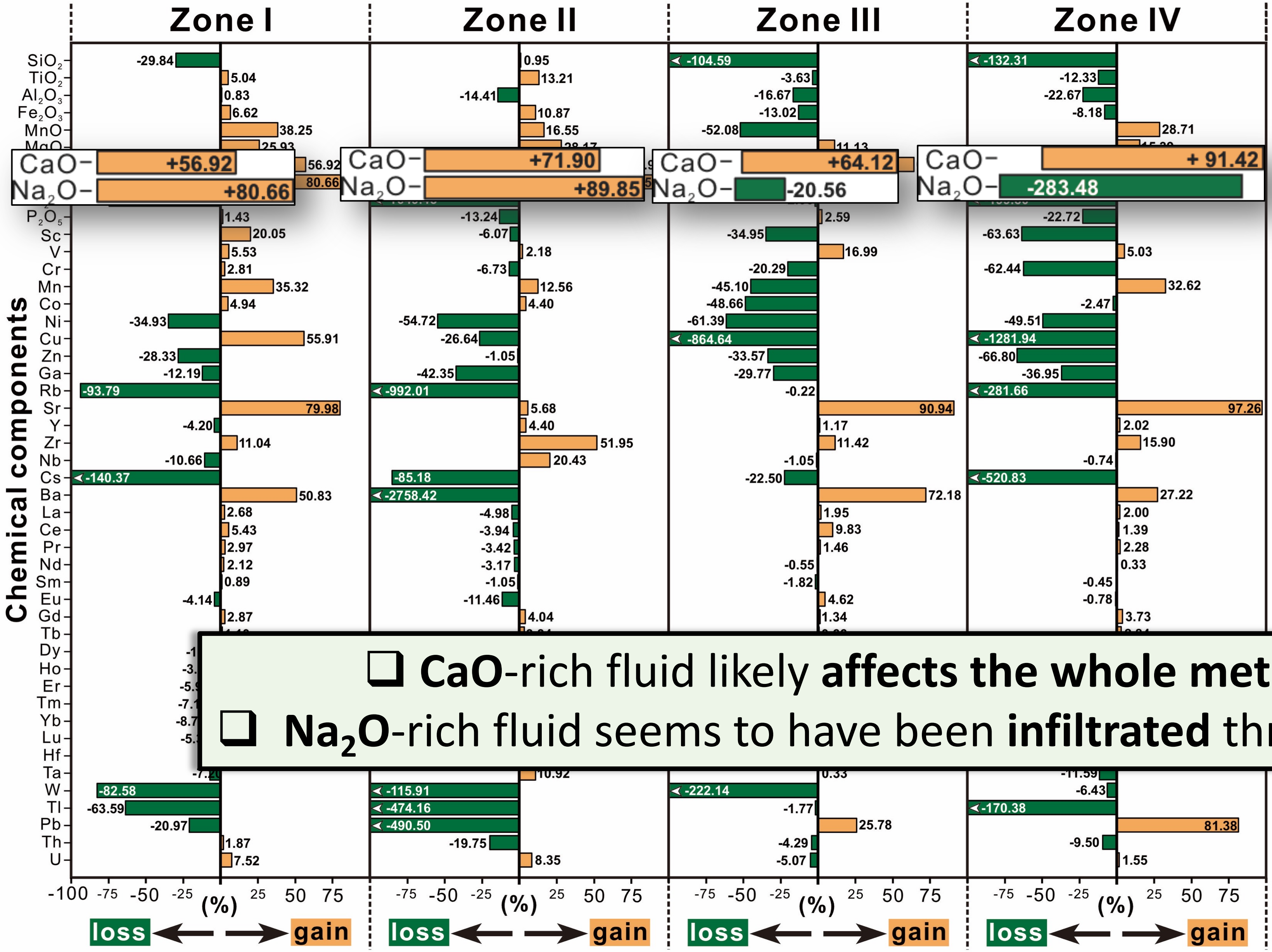


CaO concentration is gained, but Na_2O is loss

Gain or loss of component concentrations in the zone IV



Comparison gain or loss of chemical components (average)



Keypoints:

- ➢ Metasomatism intensity are likely increased from the zone I to the Zone IV.
- ➢ CaO is enriched in all zones, particulary of the zone IV.
- ➢ Na_2O only enriched in the zone I and II.

❑ **CaO**-rich fluid likely **affects the whole metasomatic zones**

❑ **Na_2O**-rich fluid seems to have been **infiltrated** through the **zone I** and **II**.

Discussion (1)

1. What is the origin of metasomatic rocks?

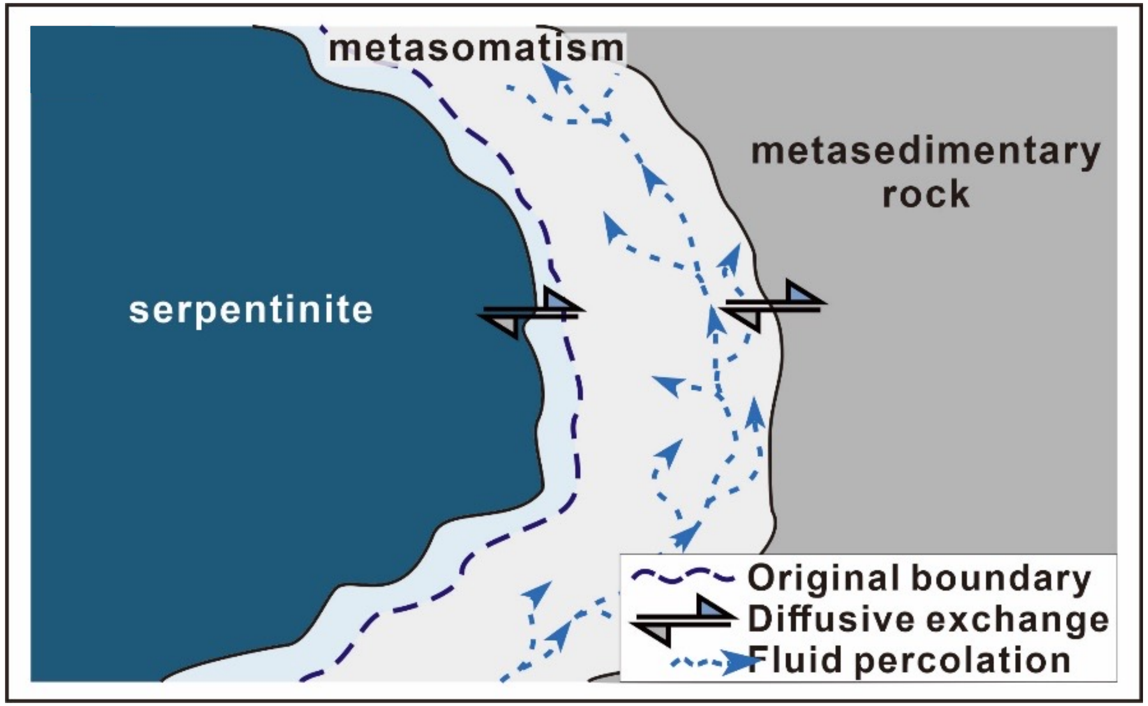
Pelitic schist	Metasomatic zones						
	Chorite-albite rock/schist	Amphibole-albite rock	Chorite-albite rock	Albite-chlorite schist	Epidote-chlorite schist	Chlorite-talc schist	Serpentinite
PS	Zone I	Zone II	Zone I	Zone III	Zone IV	Zone V	SP

Same origin (Pelitic schist – Zone IV)

Original contact boundary (between Zone IV and Zone V)

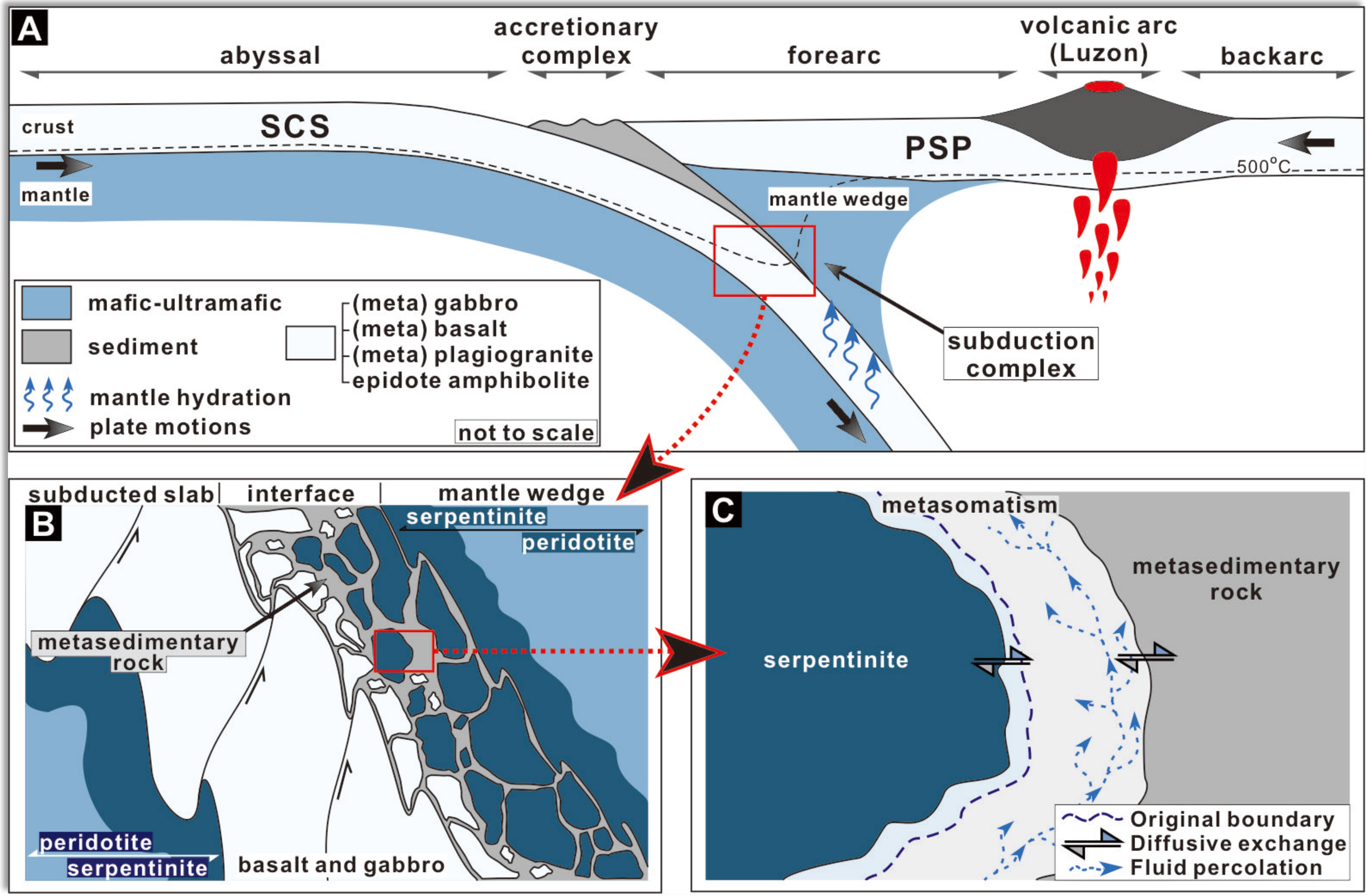
Same origin (Zone V – Serpentinite)

2. How were they formed?



1) **Diffusive exchange** of chemical components between the pelitic schist and serpentinite.
2) **Fluid infiltration** containing Na and Ca rich compositions through the metasomatic layers.

Discussion (1)



3. Tectonic implications ?

- Metasomatic rocks indicate materials from the **slab-mantle interface**.
- Metasomatic rocks record indications of **fluid-rock interactions** during **subduction metamorphism**.

Conclusions

1. **Pelitic schist** and **metasomatic zones I – IV** are from the **same origin**, whereas **zone V** is from the **serpentinite origin**. The **original contact boundary** is between zone **IV** and **V**.

2. **Diffusive exchange** and **fluid infiltration** (Na and Ca rich) are responsible for the formation of the metasomatic zones.

3. Metasomatic rocks record evidence of **fluid-rock interactions** at the **slab-mantle interface** during **subduction metamorphism**.

Reference list

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