The Geochemistry of Biotite from TTG Batholiths and A-type Complexes (Silet Region, Hoggar, Algeria): A Marker of Geodynamic Evolution

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Abstract

This work aims to compare the chemical composition of electron microprobe analysed biotite (n = 245) from four Trondhjemite-tonalite-granodiorite (TTG) batholiths and four A-type complexes. All of them are exposed in the central part of the Silet terrane (western Hoggar, Algeria) and crosscut Pharusian volcano-sedimentary series. According to Nd isotope values, the rocks are geographically arranged in two narrow N-S oriented bands separated by the Tin-Dahar fault. Negative isotopic values characterize all rocks of the narrow eastern band (ENB) ($-2.91 < \varepsilon\text{Nd} < -8.10$), and biotite is the only mafic mineral. On the other hand, in the western band, rocks display positive (WPB) isotopic values ($+0.52 < \varepsilon\text{Nd} < +4.57$) and amphibole in addition to biotite. WPB biotites are magnesian ($0.50 < \text{Mg} < 3.31$) and calc-alkaline, while ENB biotites are ferroan ($0.31 < \text{Mg} < 2.55$) and alkali-calcic to alkaline. ENB biotites are relatively poor in Altot_{ot} ($2.58 < \text{Altot}_{\text{ot}} < 2.89$) compared with WPB biotites ($2.72 < \text{Altot}_{\text{ot}} < 3.10$). On the other hand, a-type biotites have high Al tot values in the WPB rocks ($2.67 < \text{Al}_{\text{tot}} < 4.18$) compared to ENB ($2 < \text{Al}_{\text{tot}} < 3.18$). The distinctive features of the studied biotites evidence the Tin-Dahar fault as a major regional feature.

Keywords

Biotite chemistry • TTG batholiths • A-complex granite • Tin-Dahar fault • Silet • Hoggar • Algeria

1 Introduction

Like 25 other terranes in Hoggar, the Silet Terrane is located within the Tuareg shield (Liégeois, 2019). The Silet terrane considered a composite island arc (Bechiri-Benmerzoug, 2009), was accreted to the eastern margin of the LATEA meta craton during the late stage of pan-African orogeny (650–630 Ma). It comprises Neoproterozoic volcano-sedimentary series (Pharusien I and II), crosscut by TTG batholiths (870–639 Ma). The last phase of the cycle is marked by the emplacement of A-type granitic complexes of the "Taourirt" suite (Azzouni-Sekkal et al., 2020, and references therein). According to Nd whole-rock and Hf zircon isotopic ratios, rocks of the central region of the Silet terrane are geographically arranged into two narrow bands roughly oriented N-S, separated by the Tin-Dahar fault. Rocks of the eastern band (ENB) yield negative εNd ($-2.91 < \varepsilon\text{Nd} < -8.10$), while those of the western band (WPB) yield positive εNd/εHf ($+0.52 < \varepsilon\text{Nd} < +4.57$). We compared biotite chemical compositions from eight massifs, including four TTG-type batholiths: Tin-Tekadiouit, Ahambatou, Silet, and Eheli, and four A-type granitic complexes: Tin-Erit, Tioueïne, Teg-Orak, and Inedjaren (Fig. 1). The main geological, petrographic, geochemical, and geochronological features are summarized in Tables 1 and 2.

2 Materials and Methods

We selected two hundred and forty-five (245) chemical compositions of biotite, of which 44 analyses were carried out at the Museum of Natural History of Paris (Teg-Orak and Tioueine) and 201 new analyses were carried out at the

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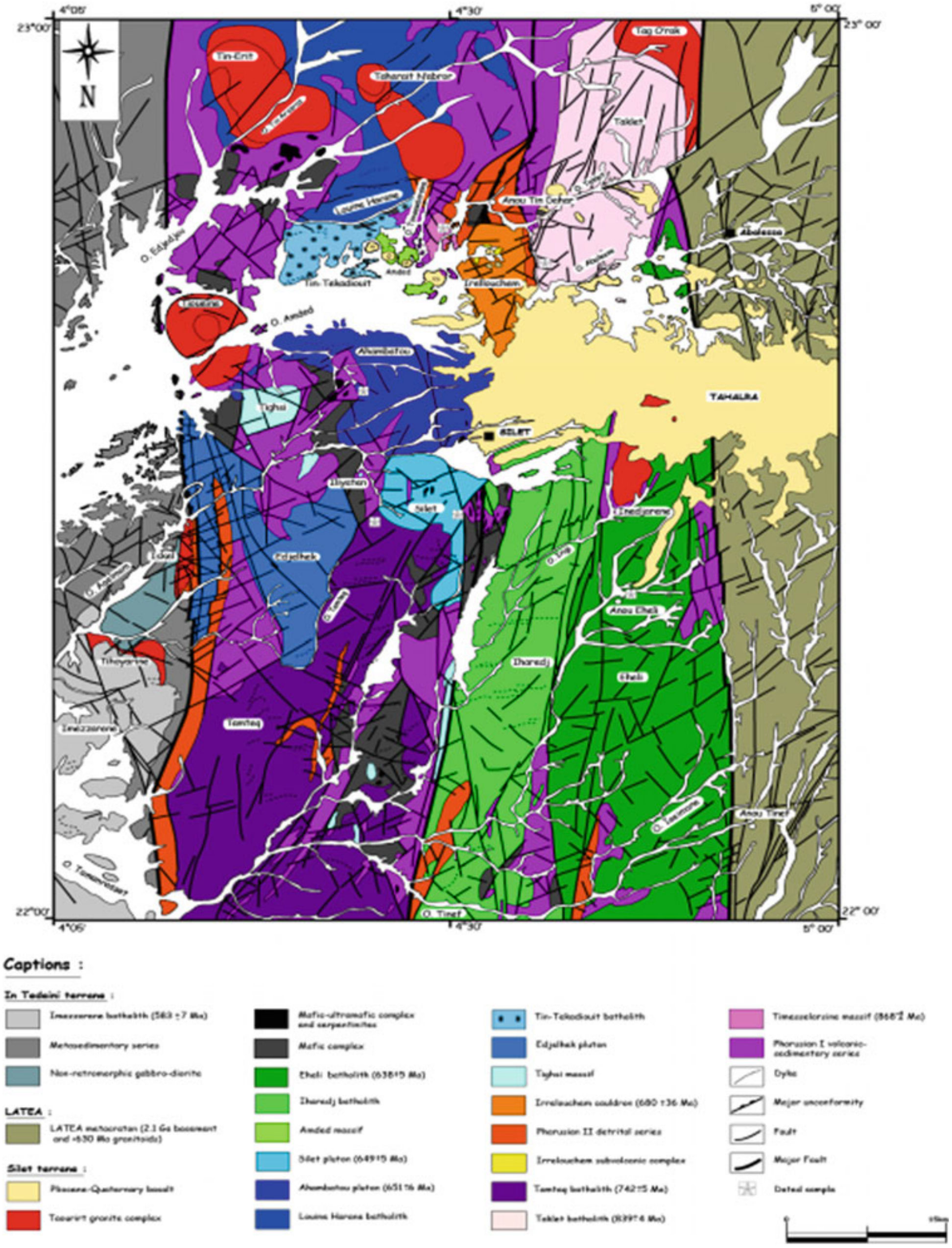

Fig. 1 Geological map of Silet area (Bechiri et al., 2016)

OSU UPMC-INSU (Sorbonne University–Paris-France) with CAMECA SX-100 microprobe for four TTG batholiths (Eheli, Ahambatou, Tin-Tekadiouit, and Silet) and two A-type granites (Tin-Erit and Inedjaren). The structural formulas, based on 22 oxygen anions, and the distribution of Fe^{2+} and Fe^{3+} were calculated using the software of Li et al.

3 Results

Black mica is a hydrated ferromagnesian silicate common in all plutonic rocks of the TTG and A-type batholiths of the western positive isotope signature (WPB): Eheli (TTG) and Inedjaren and Teg-Orak (A-type) and the biotite of the TTG (Tin-Tekadiouit, Ahambatou, and Silet) and A-type (Tin-Erit and Tioueïne) batholiths, located in the eastern band negative isotopic signature (ENB) is associated with amphibole.

Comparative results of the chemical compositions of biotites conducted in the two bands (ENB, WPB) show a distinct geochemical contrast between the biotites of the two bands, the element Mg is decreased from the biotites of the ENB granites ($0.57 < Mg < 4.20$) to the biotites of the WPB band ($0 < Mg < 2.88$). In contrast, Fet shows the opposite trend $2.14 < Fet < 6.05$ (WPB) and $1.80 < Fet < 4.23$ (ENB).

In the Feal [Fe + Mn + Ti-AlVI] vs. Mgli (Mg-Li) diagram (modified from Tischendorf et al., 1997), the

Table 1 Main petrographic and geochemical characters of the TTG batholiths

Band position	Eastern negative band	Western positive band		
Batholith age	Eheli (638 ± 5 Ma)	Silet (649 ± 5 Ma)	Tin-Tekadiouit (undated)	Ahambatou (651 ± 6 Ma)
TTG type	Sodic Low-HREE	Potassic	Potassic	Sodic Low-HREE
Rock types	Granodiorite—Monzogranite	Monzodiorite—Quartz monzonite—Syénogranite	Granodiorite	Tonalite—Granodiorite—Monzogranite
Major felsic minerals	Quartz + Oligoclase + K-feldspar		Quartz + Oligoclase-Andesine + K-feldspar	
Major mafic minerals	Biotite	Biotite ± Mg-Hornblende		
Accessory minerals	Zircon + Allanite + Titanite + Apatite + Ilmenite + Titanomagnetite			
A/CNK	Peraluminous			
Chemical affinity	Calc-alkaline to calcic	Calc-alkaline to Alkali-calcic	Calc-alkaline	
Geodynamic context	Volcanic arc granites			
εNd(t)	$-2.91 < \varepsilon\mathrm{Nd} < -8.30$	$+0.2 < \varepsilon\mathrm{Nd} < +3.27$	$+1.92 < \varepsilon\mathrm{Nd} < +4.57$	$-0.09 < \varepsilon\mathrm{Nd} < +1.22$

Table 2 Main petrographic and chemical characters of A-type granites (Silet area)

Band position	Eastern negative band		Western positive band	
Complex age	Teg-Orak (519 ± 18 Ma)	Inedjarene (Undated)	Tin-Erit (584 ± 2 Ma)	WTioueïne (561 ± 1 Ma)
Taourirt type	GI – GIIa	GIIa – GIIb	GIIa – GIII	GI – GIII
Rock types	Monzogranite—Syenogranite	Alkali feldspar Granite—Syenogranite	Monzogranite—Syenogranite—Hypersolvus granite	Monzogranite—Syenogranite—Hypersolvus granite—Syenite
Major felsic minerals	Quartz + K-feldspar + Plagioclase			
Major mafic minerals	Biotite		Biotite ± Mg-hornblende	
Accessory minerals	Zircon + Allanite + Titanite + Ilmenite + Magnetite + Apatite			
A/CNK	Metaluminous to peraluminous	Metaluminous	Metaluminous to peralkaline	Metaluminous
Alkali-calcic Alkaline	Alkali-calcic—Alkaline	Alkali-calcic	Alkali-calcic—Alkaline	Alkali-calcic—Peralkaline
Geodynamic site	Syn-kinematic within-plate granite	Within-plate granite	Syn-kinematic within-plate granite	Syn-kinematic within-plate granite
εNd(t) / εHf(t)	$-5.18 < \varepsilon Nd < -8.38$	/	$+5.54 < \varepsilon Hf < +11.99$	$+2.2 < \varepsilon Hf < +7.1$

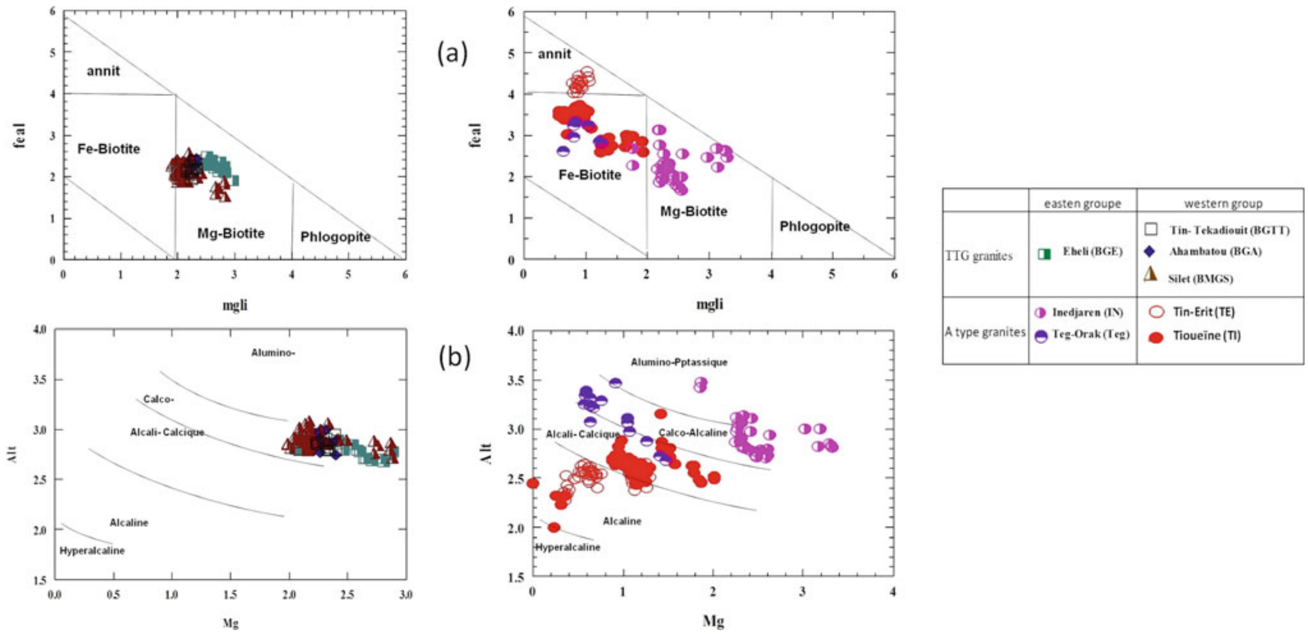

Fig. 2 Chemical compositions of TTG and A-type granite biotites of the Silet area **a** feal (Fe + Mn + Ti–AlVI) versus mgli (Mg–Li) (Tischendorf et al., 1997) and **b** Mg versus $\mathrm{Al_{tot}}$

compositions of the black micas of TTG and A-type granites show an evolution from the ENB band group (Mg-biotite,) except the Teg-Orak batholith biotite which is less magnesian and lies in the Fe-biotite field, to the WPB band group where the biotite is more ferriferous which straddles the Fe-biotite field for TTG granites and approaches the annite pole for A-type granites (Fig. 2a).

In the Alt/Mg magmatic affinity diagram of Nachit et al., we find a certain similarity between the different micas of the granites studied in the two bands as regards the evolution from the most magnesian biotites of the eastern band (TTG and A-type) which are similar to the Calco-Alkaline to Alkali-Calcic to the least magnesian biotites which characterizes the Western band (A-type) draw a trend going from the domain Alkali-Calcic towards the domain Alkaline for the granite of A-type, on the other hand, the biotites of granite of Type TTG are registered in the same line with the other biotites of the Eastern band (Calco-Alcaline) (Fig. 2b).

4 Discussion

Major oxides, FeO, MgO, Al_2O_3, and TiO_2 (not discussed here) enable the characterization of biotites (Foster, 1960, etc.). Biotite of Eheli TTG batholith is more magnesian and less alumina-rich than Tin-Tekadiouit, Ahambatou, and Silet batholiths. Biotite of Inedjaren and Teg-Orak A-type complexes show the same features, pointing to a siderophyllite end-member, while biotite of Tin-Erit and Tioueïne A-type complexes are ferroan (Azzouni-Sekkal et al., 2003). Magnesian and aluminous characteristics of Teg-Orak and Inedjaren may reflect an orogenic character, though they are anorogenic (Fig. 3).

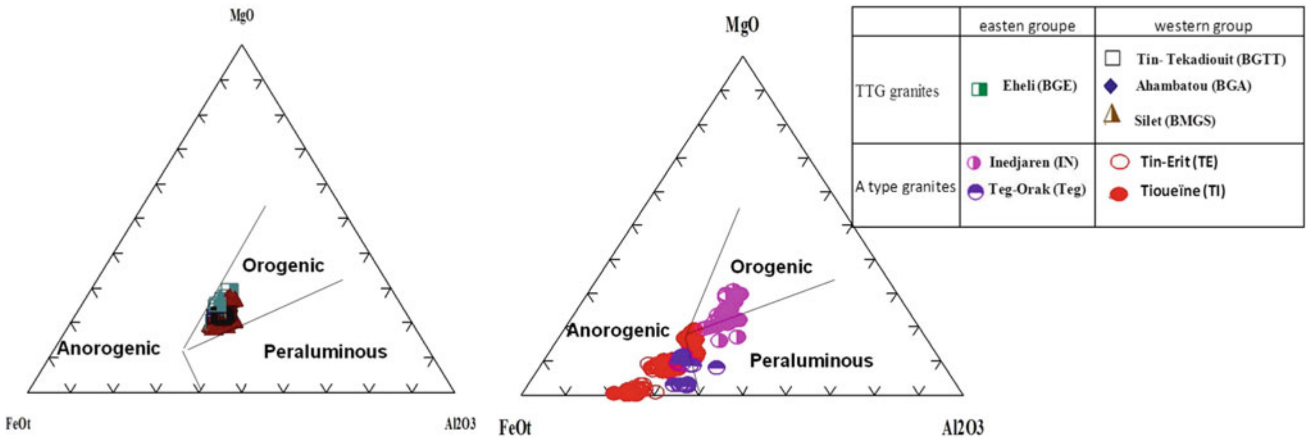

Fig. 3 Silet biotites on FeOt-MgO-Al_2O_3 discrimination ternary diagrams

5 Conclusions

The eastern band's juvenile rocks (TTG + A-type) may reflect an ocean-ocean subduction context. In contrast, those of the western band suggest a crustal contribution in their parent magmas emplaced in an ocean-continent context. This result is supported by the studied rocks' biotite compositions (Mg-biotite and Fe-biotite).

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