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Lithium isotopic composition of Alaskan-type intrusion and its implication

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ABSTRACT

To determine whether fractionation of Li isotopes could occur at high temperatures, we examined major element and Li isotopic compositions of olivine from the Xiadong intrusion, an Alaskan-type complex in the Central Asian Orogenic Belt. Olivine in thirteen dunites, displaying characteristic cumulus textures, yielded large variations in Li concentration (0.10 to 11.18 ppm) and isotopic composition (δ^7Li = −7.18 to +34.41‰). These variations are too large to be attributed entirely to diffusive processes. The correlations between Li elemental or isotopic composition and differentiation indices such as Fo and MnO contents of olivine, and NiO content of chromite, suggest probable Li isotope fractionation during early stage of differentiation. We speculate that while Li behaves mildly incompatible during differentiation, ^{7}Li is preferentially incorporated into olivine relative to ^{6}Li during early stage crystallization from arc magmas. Relatively high Li concentrations and low δ^7Li in arc magmas might be the result of substantial olivine fractionation prior to eruption.

1. Introduction

A general principle in stable isotope geochemistry is that fractionation occurring at mantle or magmatic temperatures tends to be small as the fractionation decreases with the square of the temperature (Chacko et al., 2001; White, 2015). This is also the case for the stable Li isotopes, ^{6}Li and ^{7}Li, which, in several intra-plate oceanic volcanic suites, show no measurable variations (Chan and Frey, 2003; Tomascak et al., 1999). The implications for this are that magmatic rocks whose Li isotopes show significant variations from the mantle might have either been affected by low-temperature processes or probably contain a component that once occurred on the surface of the Earth. The latter inference represents an important assumption in using Li isotopes as a tracer of crustal recycling (see reviews in Chapter 6 by Tomascak et al., 2016). If Li isotope fractionation during differentiation is demonstrated, its effect and magnitude should be quantified to refine the previous interpretation based on the absence of Li fractionation during high-T processes.

Tomascak et al. (1999) and Chan and Frey (2003) chose intra-plate oceanic volcanic suites to study the effect of basalt differentiation to avoid contributions of slab-derived Li and Li from the continental crust. The approach used was to examine the Li isotopic variations in bulk-rock samples obtained in solution by multi-collector inductively-coupled plasma mass spectrometry (MC-ICP-MS), with the assumption that all samples evolved along a common liquid line of descent. An additional way was to compare Li isotopic data of phenocrysts and bulk matrix separated from a given sample (Chan and Frey, 2003). Both studies concluded that Li isotopes do not fractionate during basalt differentiation. However, such results obtained from intra-plate volcanic suites might not be equally applied to basaltic magmas in different tectonic settings (Ackerman et al., 2015; Marks et al., 2007; Schuessler et al., 2009; Teng et al., 2006). Several recent investigations have highlighted the possibility of high-temperature fractionation of Li isotopes. For example, the study of Weyer and Seitz (2012) revealed substantial variability in Li concentrations and isotopic compositions between olivine and basaltic matrix, implying that Li isotopes might fractionate at magmatic temperatures. More recently, Li isotope fractionation has been observed in mare basalts and was attributed to large-degree, high-temperature igneous differentiation of their source regions (Day et al., 2016).

The capability to analyze olivine and pyroxene grains for Li isotopes by secondary ion mass spectrometry (SIMS) with high spatial resolution allows a more detailed examination of isotope fractionation down to the

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grain scale. This, therefore, serves as the motivation for a study of Li isotopes in olivine from Alaskan-type intrusive rocks that formed by hydrous basaltic magmas in arc roots (Irvine, 1974; Taylor, 1967). If magma differentiation does not fractionate Li isotopes, then we should expect similar Li isotopic compositions between arc magmas and their early cumulates that are complementary to differentiation. Here, we report the Li isotopic compositions of olivine grains from 12 chromite-bearing dunite samples with characteristic cumulus texture from the Xiadong Alaskan-type intrusion in the Central Asian Orogenic Belt (CAOB). Like other Alaskan-type intrusions worldwide, the Xiadong intrusion was solidified from a hydrous arc-related parental magma without significant crustal contamination (Su et al., 2014). It is highly fractionated in lithology with simple mineral assemblage in individual rock types (Su et al., 2012). These features make the Xiadong olivine an ideal tool to investigate Li isotope fractionation during magma differentiation and evolution of arc magma at sub-volcanic depth.

2. Samples and methods

The Xiadong intrusion is an Alaskan-type intrusion in the southern margin of the CAOB and consists of dunite, clinopyroxenite, hornblendite and gabbro (Su et al., 2012). The dunites are made up of olivine (80–95 vol.%) and chromite (5–20 vol.%) and show cumulus texture. The samples selected for Li isotope analysis are mostly fresh as shown in Fig. 1a, but one of them (09XDTC1-35) is highly serpentinized and only relics of olivine and chromite are present (Fig. 1b). The olivine in these dunites displays large chemical variations in Fo (92.3–96.6) and NiO (0.05–0.76 wt.%) (Bai et al., 2017; Su et al., 2012; Sun et al., 2009). Chromite is compositionally Fe^{3+}-bearing chromite or Cr-magnetite and follows a differentiation (Fe enrichment) trend from an intermediate Cr-Al-rich spinel to Cr-magnetite. The NiO and MnO contents of the chromite range from 0.37 to1.02 wt.% and 0.05 to 1.18 wt.%, respectively. These dunites, having high MgO contents (39.7–44.5 wt.%), were considered as ultramafic cumulates of primitive arc magmas (Su et al., 2014).

Thin sections of the samples were gold-coated for in-situ Li isotope analyses using a Cameca IMS-1280HR in the Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing, China, following similar methods as in Decitre et al. (2002). Because the studied olivine is fine-grained, we conducted only one analysis on each grain. The working conditions are described in Su et al. (2015, 2016). Olivine samples 06JY-34Ol and 06JY-31Ol (Su et al., 2015) were used as standards and yielded homogeneous Li isotopic compositions. Matrix effect, of which δ^7Li increased by 1.0 ‰ for each mole percent decrease in the Fo of olivine (Su et al., 2015), was considered for calibration. The Li isotopic compositions of olivine separates from two samples (09XDTC1-24 and 09XDTC1-25) measured by solution MC-ICP-MS at the Centre de Recherches Petrographiques et Geochimiques, Nancy, France (Vigier et al., 2008), are also reported here. Notably, 09XDTC1-24Ol has been developed as standard for in situ Li isotope analysis owing to its compositional homogeneity (Su et al., 2015).

3. Results

Lithium isotopic compositions of olivine and selected geochemical parameters of the dunites are listed in Table 1. Generally, the Li concentrations and δ^7Li values of the olivine show large variations from 0.10 to 11.18 ppm and −7.18 to +34.4‰, respectively, and they are negatively correlated (Fig. 2). The olivine grains are relatively homogeneous in Li concentration, but display variable Li isotopes in individual samples (Table 1). The δ^7Li value of sample 09XDTC1-25 measured by MC-ICP-MS falls within the range for olivine from the same sample analyzed

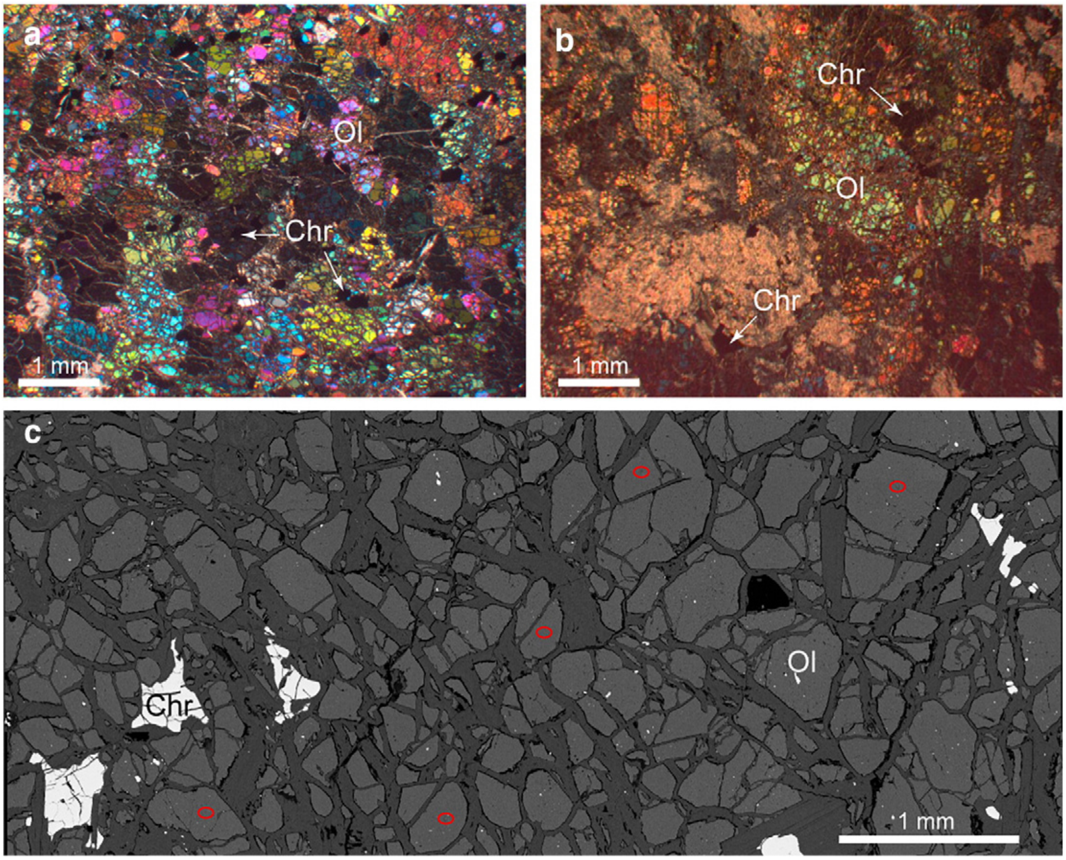

Fig. 1. Photomicrographs of the dunites from the Xiadong mafic-ultramafic intrusion. (a) Fresh sample 09XD-1 consisting of olivine (Ol) with well-developed fractures, interstitial chromite (Chr) and chromite inclusion in olivine. (b) Preserved olivine and chromite relics in highly altered sample 09XDTC1-35. (c) Back-scattered electron image of sample 09XDTC1-32 showing spot analysis locations (red ellipse).

Table 1
Li elemental and isotopic compositions of olivine and selected geochemical parameters in the dunites from the Xiadong Alaskan-type intrusion.

Sample@grain	δ^7Li	1se[a]	Li	1se[a]	Fo in Ol[b]	MnO in Chr[b]	NiO in Chr[b]
	‰		ppm			wt.%	wt.%
MC-ICP-MS							
09XDTC1-24	8.91	0.11	1.49	0.03	94.2	0.39	1.01
09XDTC1-25	13.10	0.11	1.61	0.06	96.4	0.22	0.96
SIMS							
09XDTC1-16@1	3.91	1.32	1.96	0.01	95.1	0.25	0.68
09XDTC1-16@2	9.18	1.46	2.71	0.03			
09XDTC1-16@3	13.27	1.02	2.84	0.03			
09XDTC1-16@4	5.50	0.49	1.53	0.01			
09XDTC1-16@5	7.98	0.53	1.48	0.01			
09XDTC1-16@6	−0.24	0.60	2.29	0.02			
09XDTC1-16@7	1.97	0.93	1.47	0.02			
Average	5.94		2.04				
09XDTC1-15@1	4.65	0.53	2.19	0.03	94.5	0.41	0.56
09XDTC1-15@2	2.89	0.44	3.06	0.03			
09XDTC1-15@3	3.03	0.43	2.80	0.02			
09XDTC1-15@4	5.64	0.43	2.72	0.02			
09XDTC1-15@5	4.90	0.59	1.98	0.02			
09XDTC1-15@6	9.20	0.56	1.46	0.01			
Average	5.05		2.37				
09XDTC1-32@1	5.43	0.47	2.76	0.03	96.5	0.65	0.64
09XDTC1-32@2	−7.18	0.40	3.80	0.04			
09XDTC1-32@3	3.77	0.49	3.86	0.04			
09XDTC1-32@4	2.31	0.41	3.25	0.03			
09XDTC1-32@5	−4.17	0.37	3.45	0.03			
Average	0.03		3.42				
09XD-1@1	4.39	0.30	7.18	0.07	95.2	0.57	0.81
09XD-1@2	12.31	0.42	2.26	0.02			
09XD-1@3	13.57	0.43	3.60	0.04			
09XD-1@4	6.58	0.34	5.04	0.05			
09XD-1@5	12.05	0.44	2.22	0.02			
Average	9.78		4.06				
09XDTC1-11@1	1.83	0.39	6.39	0.05	92.6	0.76	0.62
09XDTC1-11@2	3.51	0.37	5.85	0.05			
09XDTC1-11@3	1.47	0.43	5.57	0.02			
09XDTC1-11@4	4.90	0.38	4.25	0.04			
Average	2.93		5.52				
09XDTC1-31@1	1.65	0.49	6.76	0.05	94.2		
09XDTC1-31@2	0.71	0.39	9.46	0.08			
09XDTC1-31@3	2.29	0.40	9.82	0.09			
09XDTC1-31@4	0.99	0.41	5.94	0.05			
Average	1.41		8.00				
09XDTC1-19@1	−2.59	0.42	5.95	0.06	93.0	1.18	0.45
09XDTC1-19@2	−6.08	0.39	10.72	0.10			
09XDTC1-19@3	2.98	0.58	2.45	0.02			
09XDTC1-19@4	−4.80	0.37	11.18	0.14			
Average	−2.62		7.57				
09XDTC1-28@1	11.25	0.48	2.11	0.02	95.7	0.48	1.02
09XDTC1-28@2	17.96	0.81	1.12	0.01			
09XDTC1-28@3	11.15	0.52	2.30	0.02			
09XDTC1-28@4	11.90	0.53	1.81	0.02			
09XDTC1-28@5	12.32	0.56	1.64	0.01			
09XDTC1-28@6	14.83	0.75	0.94	0.01			
09XDTC1-28@7	23.21	1.37	0.28	0.00			
09XDTC1-28@8	16.12	1.15	0.40	0.01			
09XDTC1-28@9	18.68	1.84	0.22	0.00			
09XDTC1-28@10	20.10	1.15	0.40	0.00			
09XDTC1-28@11	19.13	1.08	0.49	0.01			
09XDTC1-28@12	20.89	1.03	0.54	0.01			
Average	16.46		1.02				
09XDTC1-25@1	13.19	1.52	0.24	0.00	96.4	0.22	0.96
09XDTC1-25@2	6.17	1.23	0.37	0.00			
09XDTC1-25@3	11.45	0.97	0.60	0.01			
09XDTC1-25@4	−0.77	1.18	0.41	0.00			
09XDTC1-25@5	16.99	1.85	0.16	0.00			
09XDTC1-25@6	11.46	1.70	0.19	0.00			
09XDTC1-25@7	12.25	1.80	0.17	0.00			
09XDTC1-25@8	13.39	1.17	0.41	0.00			
09XDTC1-25@9	11.25	1.52	0.24	0.00			
09XDTC1-25@10	7.35	1.87	0.16	0.00			
09XDTC1-25@11	7.22	1.26	0.36	0.00			
09XDTC1-25@12	−2.88	1.47	0.26	0.00			
Average	8.92		0.30				
09XDTC1-35@1	22.06	2.85	0.16	0.00	95.0	0.05	0.37
09XDTC1-35@2	20.55	1.84	0.17	0.00			
09XDTC1-35@3	34.41	2.39	0.10	0.00			
09XDTC1-35@4	23.80	2.17	0.12	0.00			
09XDTC1-35@5	23.38	2.04	0.14	0.00			
09XDTC1-35@6	23.37	2.06	0.13	0.00			
09XDTC1-35@7	25.90	2.09	0.13	0.00			
09XDTC1-35@8	27.58	2.30	0.20	0.00			
Average	25.13		0.14				
09XDTC1-36@1	13.59	1.04	0.61	0.01	95.9	0.52	0.73
09XDTC1-36@2	5.06	0.63	1.49	0.01			
09XDTC1-36@3	16.03	1.38	0.44	0.00			
09XDTC1-36@4	7.09	0.67	1.25	0.01			
09XDTC1-36@5	8.99	0.82	1.00	0.00			
09XDTC1-36@6	4.09	0.85	1.27	0.01			
09XDTC1-36@7	8.83	0.86	0.87	0.01			
09XDTC1-36@8	8.60	0.89	0.80	0.01			
Average	9.04		0.97				
09XDTC1-29@1	19.47	2.37	0.12	0.00	96.0	0.26	0.86
09XDTC1-29@2	18.05	2.54	0.33	0.00			
Average	18.76		0.23				

Ol, olivine. Chr, chromite.

[a] se = standard deviation.

[b] Data are from Su et al. (2012).

by SIMS. On the contrary, the corresponding Li concentration is apparently higher than the values measured by SIMS, possibly due to the presence of minor serpentine in the fractures of the olivine separates (Decitre et al., 2002; Vils et al., 2009). The olivine grains in sample 09XDTC1-35 have the lowest Li concentration and the highest δ^7Li value (Table 1).

4. Discussion

4.1. Primary features of Li isotopes

Lithium isotopes are sensitive to low-temperature fluid–rock interaction due to high mobility of Li and large mass difference between ^{6}Li and ^{7}Li (Chan et al., 2002). During serpentinization, Li and preferentially ^{6}Li are leached from olivine grains to hydrothermal fluid, causing the olivine to become Li-depleted and isotopically heavier (Chan et al., 2002; Decitre et al., 2002; Lundstrom et al., 2005; Wimpenny et al., 2010; Wunder et al., 2010). This process can explain the extreme δ^7Li in the olivine from the highly serpentinized sample 09XDTC1-35, and its subsequent shift from the compositional trend defined by the majority of the samples (Fig. 3). Crustal contamination commonly occurs during

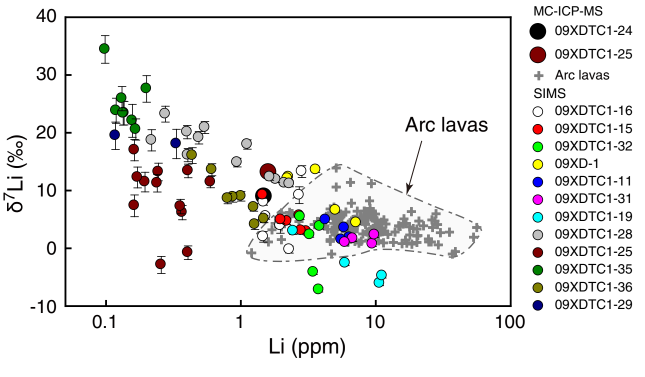

Fig. 2. Li versus δ^7Li in olivine from the Xiadong dunites. Data of arc lavas plotted for comparison are from Košler et al. (2009), Chan et al. (2002), Magna et al. (2006), Tang et al. (2014), and Tomascak et al. (2000, 2002).

magma ascent and emplacement, and could potentially elevate the Li content of magmas and modify their Li isotopic composition (Teng et al., 2004). For the Xiadong dunite, high MgO and low rare earth element concentrations (Su et al., 2014), along with low Li concentrations of the olivine (Table 1), suggest negligible crustal contamination.

Additionally, chemical exchange between olivine and chromite plays an important role in modifying their respective original compositions (Bai et al., 2017; Dauphas et al., 2010; Jackson, 1969; Roeder et al., 1979; Teng et al., 2011; Xiao et al., 2016). It is generally accepted that, with decreasing temperature, diffusion of Fe occurs from olivine to chromite, and vice versa for Mg, causing the Fo content of olivine to increase (Bai et al., 2017; Su et al., 2012). Although Lenaz et al. (2017) showed that the content of Li in spinel from African mantle xenoliths falls within the range of 0.1–1.5 ppm, our measurement demonstrates much lower ^{7}Li$^+$ count rates for chromite (several thousand cps/nA) than those for olivine (hundreds of thousands cps/nA), reflecting the extremely low Li concentration in the chromite. As a consequence, the chemical exchange should not affect the olivine in terms of Li concentration and its isotopic composition. Previous studies (e.g., Lundstrom et al., 2005; Tomascak et al., 2016) have revealed that diffusion of Li into a mineral should produce a negative anomaly of around 10–20‰ for δ^7Li since ^{6}Li diffuses slightly faster than ^{7}Li. Such diffusion mechanism may account for the negative correlation between Li and δ^7Li in the Xiadong olivine (Fig. 2) but cannot explain variability of the entire dataset (30‰ variation in δ^7Li) and their correlations with indicators of magma differentiation (Fig. 3).

During the growth of a mineral from a fluid or melt, intra-crystalline diffusion driven by a chemical or isotopic gradient could affect the Li concentration of the mineral (Tomascak et al., 2016). During olivine growth, the establishments of Li concentration and Li isotopic gradients cause such diffusion to result in uniform Li concentration relative to δ^7Li of olivine in an individual sample, since it takes longer time for Li isotopes, compared to Li abundance to achieve compositional uniformity (Richter et al., 2014). This appears to be consistent with our data, pointing to the limited Li variations compared to the wide range of δ^7Li values in individual samples (Fig. 2; Table 1). For example, the homogeneous Fo content relative to Li and δ^7Li in a given Xiadong sample (Su et al., 2012, 2015) can be ascribed to 4–8 times faster Fe-Mg exchange in olivine than Li diffusion in olivine (Parkinson et al., 2007). However, the large variations in Fo, Li and δ^7Li displayed by our entire dataset cannot be explained by the intra-crystalline diffusion mechanism (Fig. 3).

Therefore, we conclude that all the olivine grains in the Xiadong dunites, except those in sample 09XDTC1-35, preserve the primary Li concentration and isotopic compositions during crystallization. Given that the mineral assemblage in the dunites consists of only olivine and chromite, and the fact that the chromite contains little or no Li, we assume that the Li concentrations and isotopic values in olivine of the Xiadong dunites are representative of the whole rock samples.

4.2. Li isotope fractionation during magma differentiation

Lithium is moderately incompatible during mantle melting and magma differentiation (Brenan et al., 1998). This behavior indicates that the concentration of Li in magmas increase with increasing degrees of differentiation (e.g., Hamelin et al., 2009; Marks et al., 2007). This is consistent with the study of Weyer and Seitz (2012) who analyzed matrix and olivine phenocryst of several basaltic rocks, showing lower Li concentration in olivine than the matrix in all instances. Large extents of fractional crystallization of olivine have also been interpreted to account for the elevated Li contents of some phonolites (Ackerman et al., 2015). The Xiadong olivine shows a trend of increasing Li with decreasing Fo (Fig. 3a). Furthermore, the Li content of olivine is correlated negatively with NiO and positively with MnO in chromite (Fig. 3b, c). Collectively, these trends are consistent with variable degrees of magma differentiation. The results demonstrate that olivine fractionation drives the derivative magma towards high Li. Such elevated Li trends are thought to be related to redox conditions of the magmas (Marks et al., 2007). This is evidenced by increasing partition coefficient of Li between olivine and melt with the increasing concentration of trivalent cations in the melt, which are capable of being associated with Li within the olivine structure (Grant and Wood, 2010). Thus, the highly oxidized nature of the parental magmas of the Xiadong Alaskan-type intrusion (Su et al., 2012, 2014) may enhance the fractionation of Li in the olivine.

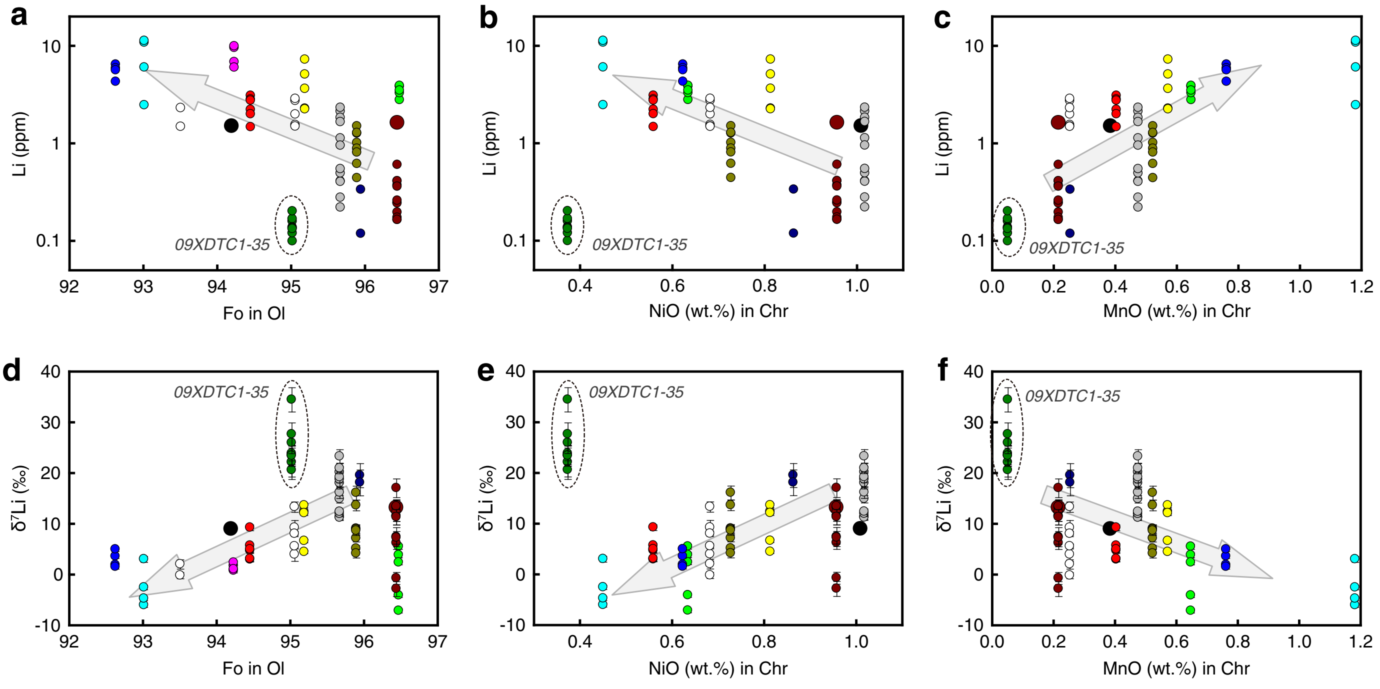

Fig. 3. Correlation diagrams of Li and δ^7Li vs. Fo in olivine, NiO and MnO in chromite for the Xiadong dunites. Arrows represent magma differentiation trend.

Theoretically, Li isotope fractionation is produced by different coordination numbers for Li between melts and crystals (Teng et al., 2006) as ^{7}Li appears to partition favorably into less coordinated sites with stronger Li—O bonds (Magna et al., 2013; Wunder et al., 2011). Since Li in most silicate melts is predominantly in tetrahedrally coordinated groups (Soltay and Henderson, 2005), minerals incorporating Li in sites of higher coordination should be isotopically lighter than the melt from which they crystallize (Teng et al., 2006). For example, granitic melts should evolve towards high δ^7Li values with differentiation because Li is octahedrally coordinated in most Li-rich minerals (Teng et al., 2006).

However, a compilation of global igneous rocks has revealed negative correlations between δ^7Li and Li (Tomascak et al., 2016), indicating that Li isotopic compositions tend to become lighter during magma differentiation (Magna et al., 2016). In addition, more geochemically differentiated samples of a suite of evolved granites with the lightest Li isotopic signatures revealed Li isotope fractionation during magma differentiation (Plyusnin et al., 1979). A study of differentiated lithologies of the Massif Central in France also revealed a negative correlation between Li isotopic composition (δ^7Li ≥ +0.4‰) and Li concentration, an observation consistent with fractional crystallization (Hamelin et al., 2009).

Because of similar sizes of Li and Mg cations (De Hoog et al., 2010), Li^+ preferentially substitutes for Mg^{2+} in six-fold coordinated site in olivine (Grant and Wood, 2010). Thus, olivine is expected to be isotopically lighter than the basaltic matrix, as Li in basaltic melts is believed to be in tetrahedrally coordinated groups (Soltay and Henderson, 2005). Essentially, the olivine phenocrysts analyzed by Weyer and Seitz (2012) show larger δ^7Li variation (−10.5 to +6.5‰) than the matrix (+2.5 and +4.7‰). The lower δ^7Li values of the olivine may have been produced by diffusion process from high-Li matrix to olivine, whereas the higher δ^7Li values probably represent the initial compositions of the olivine phenocrysts after crystallization. Because mantle-derived magmas reported so far have lower δ^7Li values (summary in Tomascak et al., 2016) than the olivine in this study, the much higher δ^7Li signature in the Xiadong olivine (Fig. 2) cannot be explained by theoretical calculation. Diffusion alone is not able to account for the observed Li isotopic compositions. Consequently, these olivine grains preserve primary magmatic compositions with respect to Li isotopes. The trends shown in Fig. 3d, e and f illustrate that magma differentiation caused the crystallized olivine as well as the differentiating magmas to become lighter in Li isotopes.

According to Tomascak et al. (2016), the discrepancies between theoretical calculation and actual observation through measured results could be explained by the limited application of the theoretical approach to natural open-system and diffusion effect. Additionally, Teng et al. (2006) highlighted that fluid exsolution could be responsible for the significant Li isotope fractionation in granitic systems. Apparently, the magma system of the Xiadong Alaskan-type intrusion is a quasi-closed, hydrous system (Su et al., 2012), which possibly reconciles the discrepancies.

4.3. Implications for arc magmatism

It has been well documented that Li behaves as a fluid-mobile element in aqueous transfer (Brenan et al., 1998) with ^{7}Li preferentially enriched in the fluid phase (e.g., Chan et al., 1999; Xiao et al., 2015). Therefore, the hydrous reservoirs are generally isotopically heavy (Tomascak et al., 2016). The inference is manifested in the observations of the Xiadong intrusion. Represented by olivine chemistry, the whole-rock δ^7Li values of the dunites from the Xiadong Alaskan-type intrusion are apparently higher than those in mantle peridotites and volcanic rocks and are comparable to surface water and marine sediments (Tomascak et al., 2016). The Li isotopic signature of the Xiadong dunites is compatible with the hydrous nature of the parental magmas of the intrusion, originating from a mantle wedge metasomatized by slab-derived fluids (Su et al., 2012, 2014).

Arc magmas have Li and δ^7Li ranging from 1 to 50 ppm and 0 to +8‰, respectively (e.g., Magna et al., 2006; Tang et al., 2014; Tomascak et al., 2000, 2002), overlapping the ranges of the most evolved olivine in the Xiadong dunites (Fig. 2). This similarity indicates that Li isotopic compositions of arc magmas are likely related to fractional crystallization of olivine. The cumulus olivine with heavy Li isotopes are most likely stored in the deep arc crust. Lithium isotope fractionation during arc magma differentiation is probably favored by high oxygen fugacity (Marks et al., 2007), high fluid enrichment (Teng et al., 2006), and highly differentiated lithology (Hamelin et al., 2009; Plyusnin et al., 1979), all of which are typical of the Alaskan-type complexes (Farahat and Helmy, 2006; Himmelberg and Loney, 1995; Irvine, 1974; Su et al., 2014). The above-mentioned conditions and characteristics are consistent with the geochemical behavior of Li isotopes in subduction zone, which further confirms the findings of previous studies (e.g., Marschall et al., 2007; Wunder et al., 2006; Xiao et al., 2015; Yamaji et al., 2001) regarding the preferential loss of isotopically heavy Li from subducted slab to the mantle wedge during progressive dehydration, leaving behind isotopically lighter residual slab.

5. Conclusions

The Xiadong intrusion in NW China is a well characterized Alaskan-type intrusion and represents cumulates in the early differentiation of mafic-ultramafic magmas. Lithium isotope analyses of olivine from 13 dunites of the intrusion yield the following conclusions:

(1) Olivine grains in the dunites have Li and δ^7Li variations ranging from 0.10 to 11.18 ppm and −7.18 to +34.4‰, respectively. The inter-sample and intra-crystal variations cannot be ascribed to alteration, crustal contamination, compositional exchange, or diffusion processes, but mainly represent primary Li concentrations and isotopic compositions during crystallization.
(2) The Li concentrations and δ^7Li values are well correlated with mineral chemical indices of magma differentiation, indicating Li isotope fractionation during magma differentiation. The decreasing δ^7Li value with increase of Li concentration is in accord with magma differentiation.
(3) The compositional overlap between arc magmas and the most evolved olivine in the Xiadong dunites suggests that primitive arc magmas might have been initially heavier in Li isotopes and later underwent removal of isotopically heavy olivine at depth.

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