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Potential extraterrestrial sources of lithium

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Extracting raw materials from extraterrestrial sources is a prerequisite for the expansion of our civilization into space. It will be necessary to acquire there practically all commonly used elements – including lithium. The most valuable source of this element currently appears to be lunar soil and rocks, especially K-rich rocks and breccias (>10 ppm of Li). Among the meteorites, the highest content of lithium is characterized by lunar mare basalts and gabbro, eucrites, Martian polymict breccia, nakhlites, howardites (>5 ppm), shergottites, chassignites, lunar anorthosites breccias, mesosiderites, ureilites (>2.5 ppm), diogenites, LL, angrites, H (>2 ppm), L, CM, CO, CV, EH, CI (>1.5 ppm), brachinites, aubrites, EL, CR (>1 ppm), CK and main-group pallasites (<1 ppm). This means that a potential extraterrestrial source of lithium can be the Moon, Mars, and the 4 Vesta minor planet considered as the probable parent body of HED meteorites.

Key words: meteorite, lithium, extraterrestrial resources, Moon, Mars, 4 Vesta.

INTRODUCTION

Agriculture and mining are the main foundations of human civilization. These two essential economic activities are interdependent, and their concurrent progression will determine further advances in civilization. It is thanks to advanced agriculture that most people in developed countries can live in cities. And thanks to mining, all these cities with their advanced infrastructure, devices and systems have been created. One of the most important raw materials is lithium, which has many uses, for instance in the production of lithium-ion batteries, glass, porcelain as well as in metallurgy, where it is used as degasifier, deoxidizer and desulfurizer. Lithium alloys with aluminium or magnesium are used in aeronautics and aerospace instruments. A lithium magnesium alloy shows the best strength in relation to weight among alloys. The use of lithium in the production of tritium (which decays to ^{3}He), rocket fuels or nuclear reactor coolant may also be relevant (Clayton, 2007; www.pubchem.ncbi.nlm.nih.gov, 2019).

In recent years, lithium has become metal of great importance to the global economy. This is primarily due to the use of batteries to power our laptops and smartphones. Another important factor is the growing concern for the environment and as regards dangerous climate change, which have motivated Western governments and corporations to introduce low-emission technologies, in turn increasing the popularity of electric cars and renewable energy sources (Li et al., 2018). Power plants based on renewable energy sources have the major disadvantage of being unable to produce electricity continuously. However, this problem has already been solved to some extent by Elon Musk's lithium-ion batteries dedicated to these types of power plants (www.tesla.com, 2019). It can be assumed that similar applications of lithium will be found in space exploration. Access to electricity and the ability to store it is necessary for any human activity outside the Earth. With the increase in human presence outside the Earth (personal or through robots), the demand for raw materials in the place where they are used will also increase to minimize costs. Farther in the future, it may also be necessary to import some metals, including lithium, to Earth to cover shortages associated with resource depletion.

Lithium, after hydrogen and helium, is the oldest element in the Universe. The first lithium nuclei formed only 100 seconds after the Big Bang. Four minutes after the Big Bang, there was one ^{7}Li nucleus per billion hydrogen nuclei (Jarczyk, 2007; Clayton, 2007). However, it is one of the less common light metals in the Universe. The existing lithium mostly dates to the Big Bang. In addition, some lithium was formed in stars, and a small part was created as a result of interacting interstellar matter with cosmic rays (Clayton, 2007). This is due to the low temperature of lithium decay ($2 \cdot 10^{6}$ K), much lower than the temperature necessary for its synthesis ($2 \cdot 10^{7}$ K) (Boesgaard, 1976). Of course, not all lithium is being consumed in the cores of slowly cooling stars. It is estimated that at the end of the main stage of life of our Sun-type star, 2.5% of the original lithium mass remains in it (Boesgaard, 1976). However, for obvious reasons the future extraterrestrial source of lithium will not be the stars,

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but other small bodies such as planets, moons, asteroids, and comets that inherited lithium after the death of former stars.

Lithium, with its atomic number of 3 and mass of 7 g · mol^{-1}, is the lightest metal found in the Universe. Pure lithium is soft and has a silvery-grey colour. It melts at 180.5°C, and its density is 0.534 g · cm^{-3}, so it is lighter than water. Two stable lithium isotopes are known: ^{6}Li (7.6%) and ^{7}Li (92.4%) (Clayton, 2007; www.pubchem.ncbi.nlm.nih.gov, 2019).

Lithium does not exist in its native form outside of stars, but on small cosmic bodies it forms natural chemical compounds – minerals – that can be classified into three main groups: anhydrous aluminium silicates (such as spodumene and petalite), hydrous aluminium silicates (including several types of trioctahedral and dioctahedral mica) and phosphates (mainly forming the amblygonite-montebrasite series) (Polański and Smulikowski, 1969; Kavanagh et al., 2018; Grew, 2020). The Li^{+} ion radius is 0.082 nm, which in crystallochemical terms brings it close to Mg^{2+} and Fe^{2+}. An increase in lithium content and a decrease in the Mg/Li ratio is observed in a series of magnesium rock-forming silicates: orthorhombic pyroxene–monoclinical pyroxene–amphibole–mica. Therefore, lithium accumulates primarily in granitoids, whose main magnesium aluminosilicate is biotite (a trioctahedral mica) – a significant part of lithium in the continental crust is concentrated in this mineral. The most enriched with lithium are granites associated with tin and tungsten deposits, tourmaline-bearing granites, and sodium-rich granites with riebeckite. Granites that have undergone albitization or greisenization also show a general tendency to include variable amounts of lithium minerals, such as spodumene and amblygonite. The concentration of lithium in these granites can reach up to 600 ppm in extreme cases. Lithium minerals, which may have economic value, are formed primarily from fluids in post-magmatic environments, in pegmatite-pneumatolytic deposits (Polański and Smulikowski, 1969). Pegmatite tends to accumulate lithium and other volatile elements as it solidifies last and cools very slowly (e.g., Kavanagh et al., 2018). Albite-spodumene pegmatites were the most important type of lithium deposits in the days prior to the extraction of this metal from brines. Under conditions of 500 MPa and 550–750°C, before the formation of Li-aluminosilicates, the pegmatite-forming melts are supersaturated in lithium. A model of disequilibrium fractional crystallization through liquidus undercooling explains how pegmatitic deposits of lithium formed (e.g., Maneta et al., 2015). Increased concentration of lithium has also been observed in many salt lakes, brines from oil-bearing areas as well as in high sodium chloride hot springs associated with volcanic areas and in some mineral waters. Recent studies of rhyolitic ignimbrites indicate that the lithium content in the rock as well as the isotopic composition may be dependent on post-eruptive processes, especially on their duration and degassing. This is because lithium remains mobile for a long time after eruption and diffuses easily into phenocrysts. Magma which cooled more slowly has a higher lithium content than magma which cooled quickly (Ellis et al., 2018). In the case of thermal waters, the increased content of lithium is due to the more efficient leaching of this element from the surrounding rocks by hot water (Kavanagh et al., 2018).

On Earth, resources of lithium are found mainly in brines (59%) and minerals (25%). Lithium has also been found in clays, geothermal waters, and oilfield brines (Kavanagh et al., 2018; Bowell et al., 2020). But if we only consider deposits, the proportion changes. In this case mineral deposits are 13% and brine and mineral water deposits are 87%. Based on the data from 2008, it was estimated that brines accounted for ~50% of lithium production (Kavanagh et al., 2018). This is due to significantly lower costs of obtaining lithium from brines than from minerals, and therefore, it is likely that at present this proportion is even greater.

Several methods are used for obtaining lithium (Brandt and Haus, 2010; Choubey et al., 2016; Meng et al., 2019). One of the most popular is obtaining lithium from spodumene ($LiAlSi_2O_6$) by flotation, conversion to lithium chloride (LiCl) and then through the process of electrolysis of an anhydrous mixture of lithium chloride and potassium chloride. The lithium obtained is 99.8% pure. Other methods include high-temperature extraction from spodumene using sodium carbonate (Na_2CO_3) or recovery from natural brines (www.pubchem.ncbi.nlm.nih.gov, 2019).

Lithium is widely used in modern technologies, especially in electricity storage and e-mobility (Choubey et al., 2016; Meng et al., 2019). For this reason, the author decided to appraise potential sources in the solar system beyond Earth.

MATERIAL AND METHOD

The demand for lithium has increased rapidly in recent years, and with it the interest in this element among scientists. This metal has become crucial for storing electricity, and so will also be crucial to the planned wider presence of humans beyond the Earth. This article reviews literature on lithium resources beyond Earth.

To analyse the lithium content in individual meteorite groups, the author used analytical results on 304 different meteorites published in the last 50 years, both qualitative and quantitative, from journal databases, bibliographic databases, and meteorite databases as regards an extraterrestrial source of lithium (Tera et al., 1970; Mason, 1979; Murty et al., 1983; Lodders, 1998; Seitz et al., 2006, 2007; Koblitz, 2010; Magna et al., 2015; Yang et al., 2015; Pourkhorsandi et al., 2019; www.lpi.usra.edu, 2019). Where different researchers studied the same meteorite, their results were averaged.

RESULTS

Studies of the lithium content of extraterrestrial rocks have been conducted for many years (Tera et al., 1970; Murty et al., 1983; Lodders, 1998; Seitz et al., 2006, 2007; Yang et al., 2015; Pourkhorsandi et al., 2019). These studies mainly concern meteorite material due to its relatively high availability and the possibility of conducting laboratory analyses. The results of research on rock samples supplied directly from the Moon by the Apollo missions were also incorporated.

From this research, it has been observed that metamorphic changes do not affect the lithium content of chondrites. This is shown by the analysis of lithium content in relation to Mg, Al and S performed for individual chondrite groups. Figures 1–3 clearly show that the lithium content in the chondrite rock is independent of its petrographic type. Data on the deviation from the mean content of ±20% were considered. The data were taken from the MetBase® (Koblitz, 2010). In addition, some patterns have been observed: calcium-rich achondrites (howardites, eucrites) have a higher content of lithium than calcium-poor achondrites (diogenites, ureilites) (Murty et al., 1983; Magna et al., 2014). This behaviour of lithium is as predicted because Li was transferred to igneous settings and consequently enriched eucrites, whereas diogenites and ureilites are cumulates that do not incorporate Li. Lithium is more common in non-magnetic minerals, due to its lithophilic nature (Mason, 1979; Murty et al., 1983). In iron meteorites, the lithium content is <0.01 ppm. In addition, in enstatite chondrites, lithium is chalcophile, e.g., in

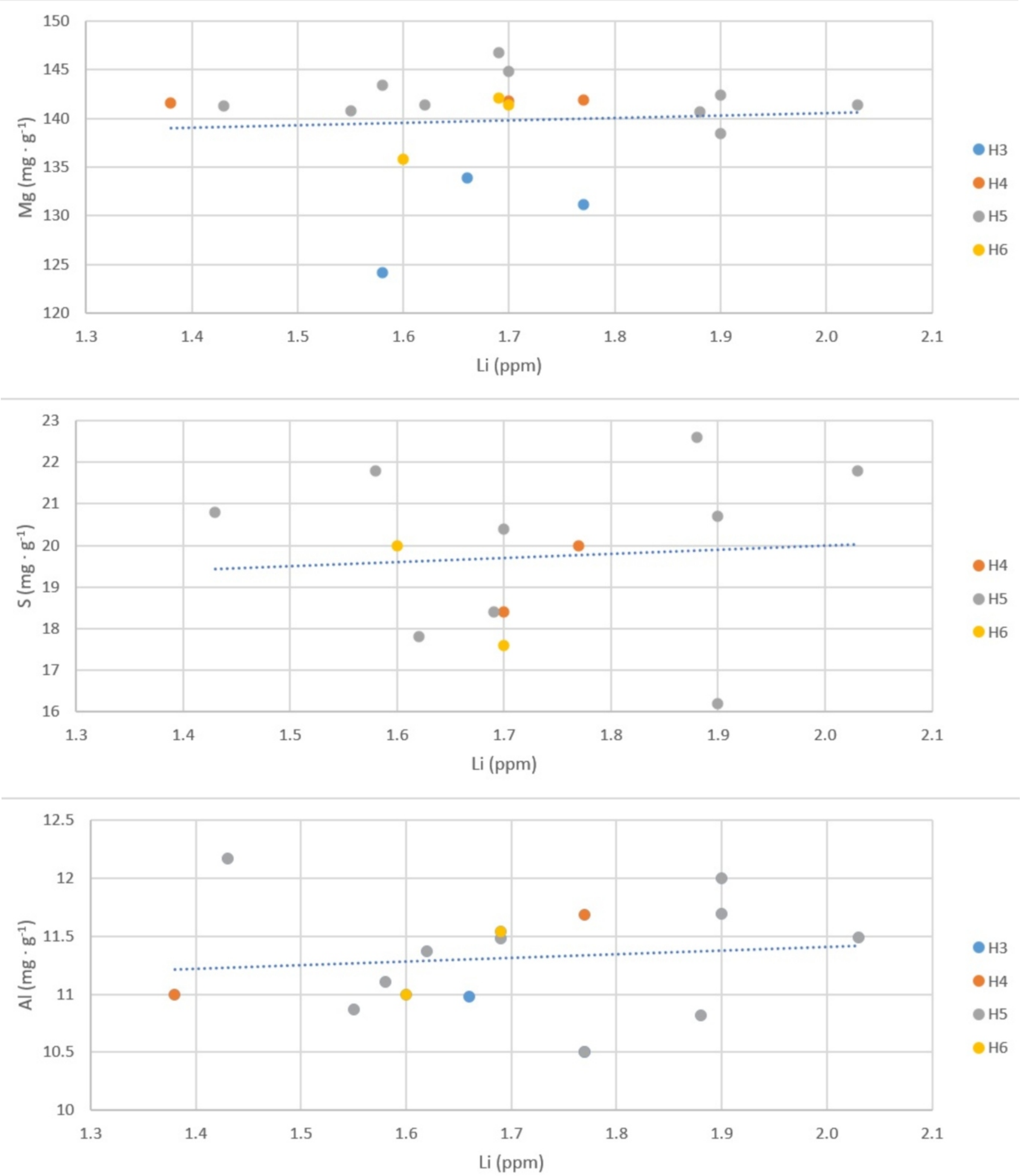

Fig. 1. Lithium content in relation to the content of Mg, Al, and S in H ordinary chondrites

chondrite Abee, two-thirds of the lithium was found in sulphides (Mason, 1979).

Lithium isotope studies may have additional useful applications. According to Sephton et al. (2013) isotope studies of ^{7}Li in carbonaceous chondrites indicate processes involving liquid water in the early stages of the formation of the Solar System and may be useful for determination of their parent bodies.

Lithium minerals outside Earth are not defined. In ordinary chondrites, lithium probably replaces the magnesium atom in the olivine structure (Mason, 1979). Lack of accurate knowledge about the occurrence of lithium in specific extraterrestrial minerals currently hinders the development of technologically feasible (and cheap) processes for obtaining this element. However, more than half a century ago, scientists were able to

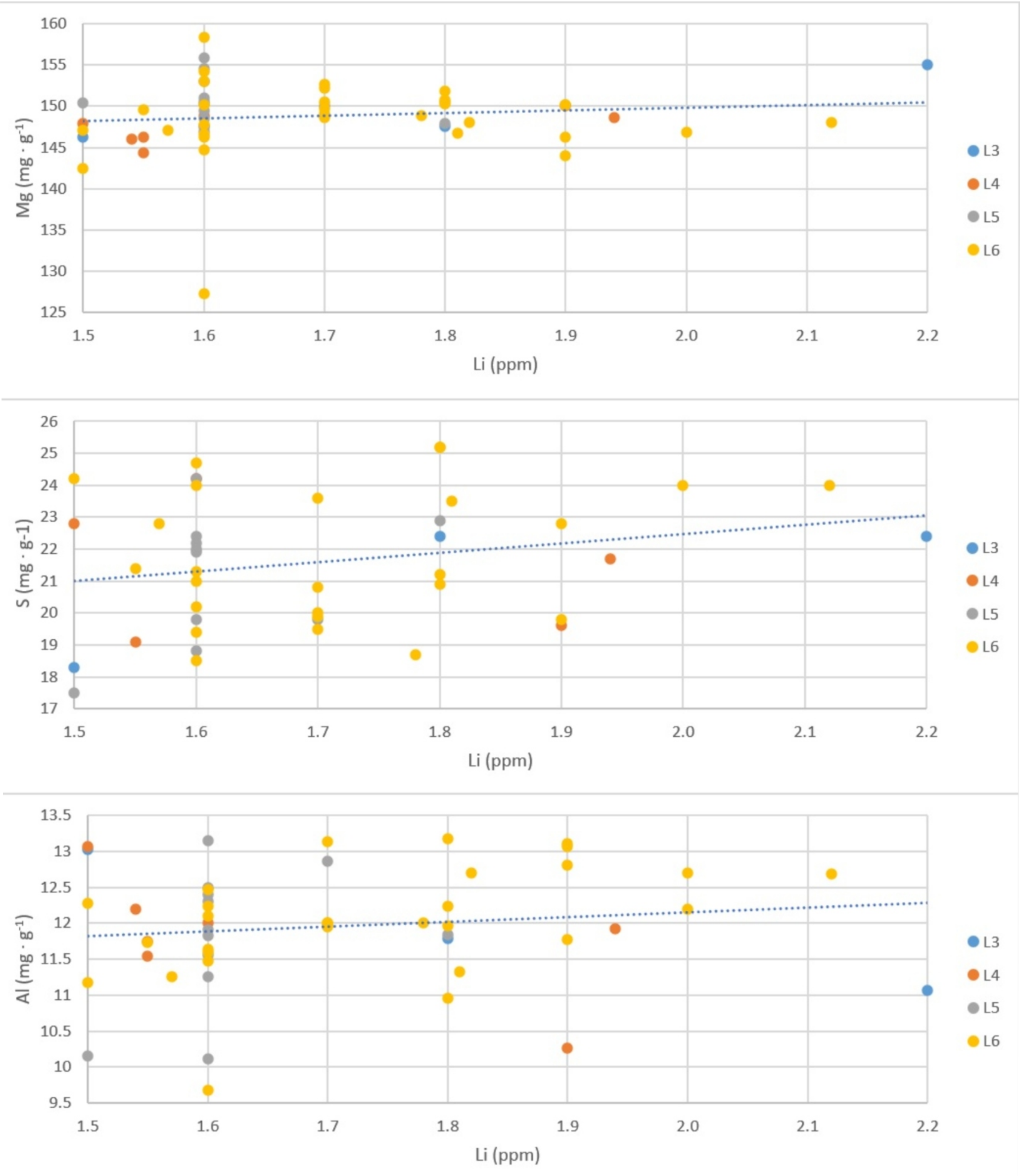

Fig. 2. Lithium content in relation to the content of Mg, Al, and S in L ordinary chondrites

obtain lithium from meteoritic matter with a purity of >90% (Dews, 1966).

Mason (1979) made the first and only attempt to determine the average lithium content for individual types of meteorites. He did this based on the results of research into 83 different meteorites. In this article I have attempted to update this data and extend it with new meteorite groups in accordance with the current meteorite classification. The new, updated data given in this article was compiled from available analytical results (Tera et al., 1970; Mason, 1979; Murty et al., 1983; Lodders, 1998; Seitz et al., 2006, 2007; Koblitz, 2010; Magna et al., 2015; Yang et al., 2015; Pourkhorsandi et al., 2019; www.lpi.usra.edu,

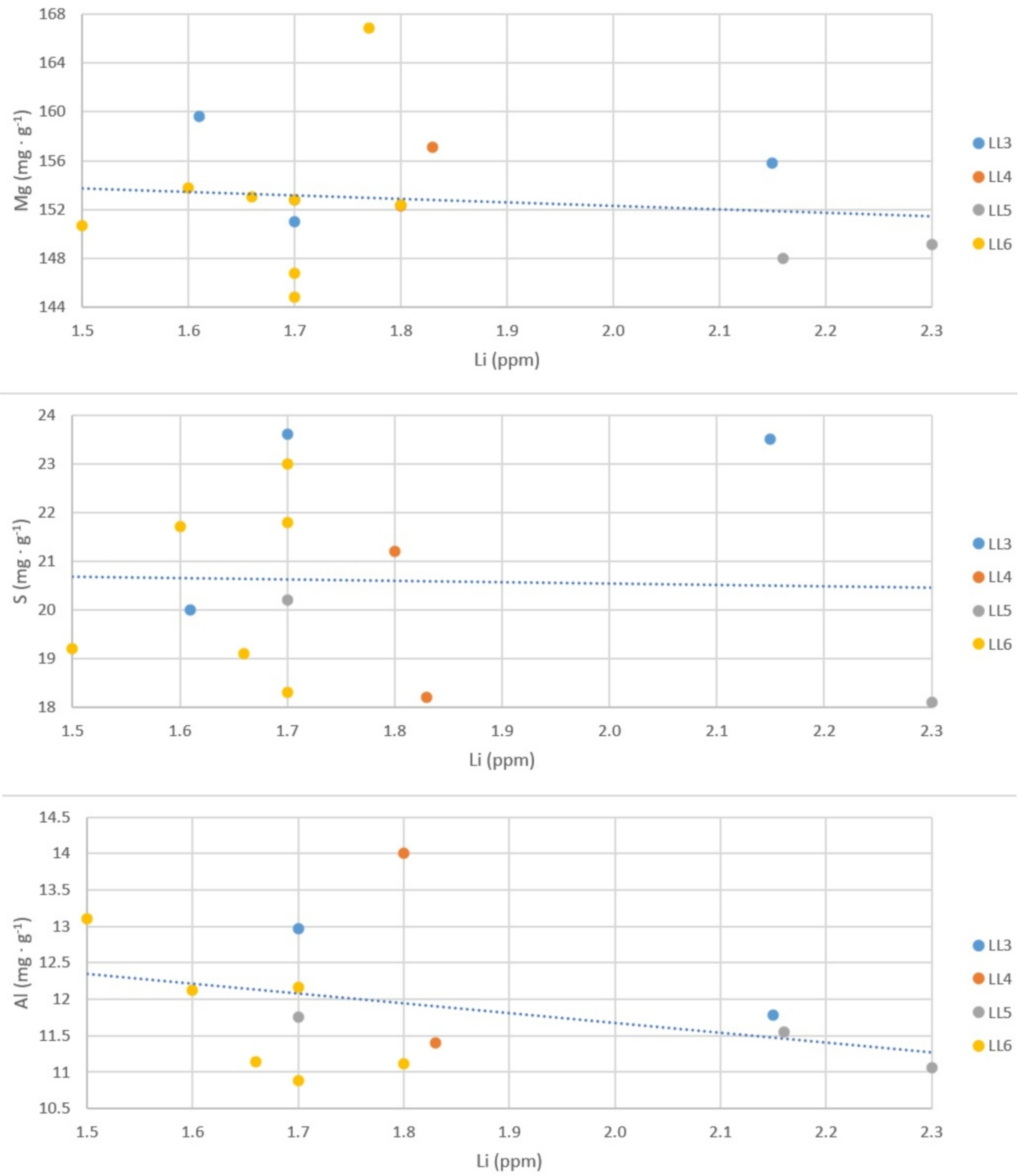

Fig. 3. Lithium content in relation to the content of Mg, Al, and S in LL ordinary chondrites

2019) for 304 different meteorites. Table 1 summarizes the results obtained by Mason (1979) and the results based on the analysis of published data. In this table, the old classification of meteorites from Mason's work is used for facilitating data comparison. When the number of analysed meteorites in the group is equal or >10, the median Li concentration values, as well as the range (minimum and maximum), were indicated.

The smallest differences (<5%) are visible in the case of angrites (probably the lithium content was taken from the same source), C1 (CI) carbonaceous chondrites, LL ordinary chondrites and diogenites. The biggest differences are seen in H ordinary chondrites (18.23%), ureilites (36.96%), eucrites (39.67%), E5,6 enstatite chondrites (72.41%) and aubrites (269.70%). However, when comparing the values proposed by

Table 1

Comparison of the average lithium content for selected meteorite groups

Group	Mason (1979)		This publication				
	Number of meteorites	Mean [ppm]	Number of meteorites	Mean [ppm]	Median [ppm]	Min [ppm]	Max [ppm]
C1 (CI)	2	1.6	1	1.52	*	*	*
C2 (CM)	5	1.7	10	1.91	1.45	1.3	6.05
C3 (CO and CV)	11	1.9	12	1.72	1.70	1.18	2.3
H	13	1.7	69	2.01	1.7	1	6.1
L	19	1.8	91	1.96	1.6	0.62	13
LL	21	2.1	20	2.14	1.7	1.5	8.2
E4	2	2.1	2	1.92	*	*	*
E5,6	2	0.58	4	1.00	*	*	*
Aubrite	1	0.33	2	1.22	*	*	*
Diogenite	1	2.2	4	2.15	*	*	*
Ureilite	1	1.84	2	2.52	*	*	*
Angrite	1	2.02	1	2.02	*	*	*
Eucrite	3	6.1	12	8.52	9.16	2.96	12.93

*<10 meteorites

Mason (1979) to the median, the conclusions are different. For chondrites, the median is less than the mean, and for eucrites the mean is less than the median. The differences are still relatively high. In all cases, the best source of lithium is achondrites from the eucrite group (6.1 and 8.52 ppm, median 9.16 ppm), leaving other meteorite groups far behind. These differences point directly to the problem of estimating extraterrestrial resources on the basis of a very small amount of research material that is directly available to us from these bodies.

Tables 2 and 3 summarizes the results of the analysis of data obtained from the previously cited publications. This table divides meteorites according to the Weisberg classification (Weisberg et al., 2006) showing the data obtained by Mason (1979), and Tables 2 and 3 includes data for almost all groups of meteorites. This was created on the basis of much more data (the results of analyses for 304 meteorites, compared to 82 for Mason, 1979).

DISCUSSION

In assessing lithium content, the results obtained can be compared with the average lithium content in the Earth's crust. For continental crust it is 18 ppm (22 ppm for upper crust and 13 ppm for lower crust) (Wedepohl, 1995). For oceanic crust it is 3.52 ppm (6.63 ppm for the mid-ocean ridge basalts) (White and Klein, 2014). The mean overall value for the Earth's crust is 7 ppm (Clayton, 2007). None of the meteorite groups is characterized by a content of lithium exceeding the content of this element in continental crust. Considering the average chemical composition of the Earth's crust overall, only 4 groups of achondrites are characterized by a higher lithium content: lunar basalts (9.65 ppm), lunar gabbro (8.6 ppm), eucrites (8.52 ppm) and Martian polymict breccia (7 ppm). Among the chondrites, the largest content is found in ordinary chondrites: LL (2.14 ppm), H (2.01 ppm) and L (1.96 ppm). It is obvious that the parent bodies of the iron meteorites will not be a source of lithium. Based on available data, the parent bodies of chondrites do not appear to be a potential source of lithium either.

In the case of the Moon analysis of the meteorite NWA 479 (lunar basalt) by Barrat et al. (2005) showed a Li content of 12.69 ppm. This study also investigated the content of Li in olivine and pyroxene crystals. For olivine, the range was 3.25 to 11.8 ppm, and for pyroxenes from 2.8 to 18.4 ppm (Barrat et al., 2005). The study of meteorites found on Earth provides much valuable information concerning distant objects of the solar system, but the most valuable material is that collected for analysis directly from the body itself. The most important hindrances when analysing the composition of meteorites are the weathering processes taking place on Earth, entirely different than in outer space, that changed the mineral and chemical composition of the rocks studied, as well as contamination of samples with terrestrial material. The Apollo missions have provided much of this type of material. We know that the lunar soil contains on average 12.5 ppm of lithium, the breccias analysed 13.9 ppm, potassium-rich rocks 17.6 ppm, and potassium-poor rocks 11.4 ppm of lithium (Tera et al., 1970). Later studies of lunar breccias have shown that they are significantly enriched in lithium: polymict highland breccia (48.8 ppm) and KREEP-rich highland breccia (13.8–21.1 ppm) (Seitz et al., 2006). The average lithium content in lunar samples is therefore ~2.5x higher than the average lithium content in the Earth's crust, in the meteorites analysed meteorites and in bulk Moon (0.83 ppm) and lunar highland crust (2 ppm) (Taylor and McLennan, 2009). Such a comparison, of course, only illustrates the situation, but it is of little importance as regards possible lithium extraction, because on Earth, lithium is extracted from mineral deposits and brines with a concentration of 0.01 to 0.2% (Flexer et al., 2018). A probable, but uncertain, source of lithium on Mars may be brines. However, there is no detailed data on the potential quantity of brines and the lithium concentration in them (Möhlmann and Thomsen, 2011).

Table 2

Average lithium content for selected chondrite groups

Type	Class	Clan	Group	Number	Median [ppm]	Mean [ppm]	Range [ppm]	
							Min	Max
Chondrites	carbonaceous chondrites	CI	CI	1	1.52	1.52	1.2[3]	1.74[3]
		CM-CO	CM	10	1.45	1.91	1.12[1][3]	6.05[5]
			CO	6	1.62	1.77	1.0[1]	2.3[2]
		CV-CK	CV	6	1.76	1.68	0.8[2]	3[3]
			CK	1	0.88	0.88	0.75[3]	1.0[2]
		CR	CR	1	1	1	1.00[1][3]	
		C-ung	–	6	1.58	1.48	1[2][3]	2.5[3]
	ordinary chondrites	H-L-LL	H	69	1.7	2.01	1[3]	6.10[4]
			L	91	1.6	1.96	0.62[3]	13.00[4]
			LL	20	1.7	2.14	1.12[3]	8.20[4]
			H/L	2	1.48	1.48	1.2[3]	1.8[2]
			L/LL	5	1.9	2.05	1.16[3]	3.53[1]
	enstatite chondrites	EH-EL	EH	4	1.7	1.54	0.81[3]	2.9[1]
			EL	3	0.86	1.06	0.52[3]	1.6[2]

[1] – Murty et al. (1983); [2] – Seitz et al. (2007); [3] – Koblitz (2010); [4] – Pourkhorsandi et al. (2019);
[5] – www.lpi.usra.edu (2019)

Table 3

Average lithium content for selected primitive achondrite and achondrite groups

Type	Class	Clan	Group	Number	Median [ppm]	Mean [ppm]	Range [ppm]	
							Min	Max
Primitive achondrites	–		brachinite	1	1.47	1.47	1.47[5]	
			ureilite	1	2.52	2.52	1.45[2][5]	5.4[5]
Achondrites	–		angrite	1	2.02	2.02	2.02[1][5]	
			aubrite	2	1.22	1.22	0.33[2][5]	2.02[1][5]
	–	HED	eucrite	12	9.16	8.52	2.95[1]	12.93[5]
			diogenite	4	2.38	2.15	0.94[2][5]	3.3[4]
			howardite	1	5.86	5.86	5.86[2][5]	
	–		mesosiderite	4	2.36	2.62	1.58[2]	2.52[2]
			main-group pallasite	3	0.43	0.41	0.012[2]	0.8[4]
	–	Moon	anorthosite	5	2.9	2.88	2.8[5]	3.2[5]
			basalt	3	11.7	9.65	3.99[5]	12.69[5]
			gabbro	1	8.6	8.6	7.6[5]	9.6[5]
	–	Mars	shergottite	29	2.96	3.27	1.2[6]	13[7]
			nakhlite	7	8.05	6.47	3.8[3][5]	12.2[3]
			chassignite	2	2.95	2.95	1.3[5]	3.9[6]
			OPX	1	2.8	2.8	2.8[6]	2.8[6]
			polymict breccia	1	7	7	7[6]	7[6]

[1] – Tera et al. (1970); [2] – Murty et al. (1983); [3] – Seitz et al. (2006); [4] – Seitz et al. (2007); [5] – Koblitz (2010);
[6] – Magna et al. (2015); [7] – Yang et al. (2015)

The presence of lithium in Martian basalt is assumed to be a consequence of the presence of water and the processes associated with it. Martian shergottites contain 280 ppm of water and nakhlites 570 ppm which distinguishes them from the Moon's basalts which are completely anhydrous (Seitz et al., 2006). Martian rocks represented by Martian meteorites have been the subject of many studies. The distribution of lithium in pyroxenes within basalts indicates the presence of water during their formation (Treiman et al., 2006). However, some scientists note the possibility of changes to the rocks after magma crystallization was completed (Herd et al., 2004). In addition, in the case of nakhlites, the possibility of enriching minerals with lithium as a result of hydrothermal processes or low-temperature aqueous alteration on the surface of Mars is also indicated (Magna et al., 2015). Interesting research results were presented by Udry et al. (2015) for rocks represented by shergottites of various compositions. In these tests, the content of lithium in the cores and rims of minerals was measured. In the case of pyroxenes, these values ranged from 0.92–5.85 ppm (augite) and 0.43–4.14 ppm (pigeonite). For maskelynite the range is 0.92–5.39 ppm and for olivine 0.41–8.53 ppm (Udry et al., 2015). Research by Beck et al. (2006) showed that in the case of shergottites, enrichment with lithium was associated with degassing of magma, while in nakhlites it was associated with diffusion from groundmass towards the pyroxenes. The values, depending on the rock and the measurement site (rim or core), for pyroxenes were 2.3–10.0 ppm, and for olivine 2.3–13.9 ppm (Beck et al., 2006). The considerable variability of measured values between samples of different rocks is due to their heterogeneity.

At the end of this comparison, the question should arise: why, in this paper, are extraterrestrial rocks with a lithium content rarely >15 ppm considered potential sources of lithium when the Earth's mineral deposits contain 0.5–2% Li? First of all, these rocks should not be treated as a source of lithium to cover Earth's shortages. Admittedly, with the increasing demand for this element for industry and the slower finding of new sources of it, the cut-off grades will decrease, but most likely not enough to be profitable to obtain lithium outside the Earth. The situation will be different outside of Earth, in potential colonies or bases on the Moon, Mars or anywhere else. All raw materials will have to be either delivered there from Earth or mined on site. Shipping costs start at $ 5,000/kg for small shipments by SpaceX or $ 5,700/kg for larger shipments by United Launch Alliance (www.foxbusiness.com, 2020). Of course, these amounts depend, among other things, on the distance, and in the case of transporting raw materials or finished products to the Moon or Mars, it would be much more expensive. This points directly to the need to become independent of supplies from Earth as soon as possible. So far, no extraterrestrial pegmatites with lithium minerals or lithium-rich brines have been found, and rocks such as K-rich lunar rocks, Martian nakhlites or eucrites are the only known potential sources of this element on extraterrestrial objects.

CONCLUSIONS

Lithium, together with any other element commonly used on Earth, will also be needed beyond the Earth. If we think seriously about colonizing other moons and planets, we must be aware that lithium will also have to be sourced on site, like the other elements. Based on the analysis presented in this publication, the best source of lithium seems to be potassium-rich moon rocks, containing an average 17.6 ppm of lithium, as well as Martian rocks, representatives of which are meteorites of the nakhlite group (7.24 ppm). Both the Moon and Mars are potentially the first extraterrestrial objects intended for colonization. Another source could be 4 Vesta or other V class asteroids, which are the likely parent bodies of HED meteorites (Magna et al., 2014). The eucrites derived from them contain on average 8.52 ppm of lithium. Howardites also have a relatively high lithium content (5.86 ppm).

The differences between the compilation of Mason (1979) and the new compilation given in this publication is primarily a much larger number of meteorites and groups of meteorites taken into account compiled according to the currently accepted classification. This comparison indicates a big problem related to the small amount of data, even after over 40 years of new research. This is due to the lack of the need to measure lithium content in meteorites. Elemental analyses involving lithium are expensive, and many research devices, that are used for research (e.g., a microprobe), are not able to measure lithium. Due to these factors, this type of research is usually neglected.

The results provided in this publication are average values and the lithium content for individual meteorites may differ significantly from this value. For example, the average lithium content for ordinary chondrites of the L group is 1.96 ppm. Among 91 L chondrites there can be distinguished Mezö-Madaras with a three times lower lithium content – 0.62 ppm (Koblitz, 2010) and CeC 006 with over six times more lithium – 13 ppm (Pourkhorsandi et al., 2019) but in the case of these chondrites this rather indicates contamination of the samples with terrestrial material or advanced weathering processes. Such high lithium content is mainly characterized by eucrites and Martian nakhlites. This indicates a scarcity of research as regards the lithium content of meteorites and extraterrestrial rocks.

From the perspective of mining on Earth, the proposed lithium sources do not seem appropriate. However, it should be emphasized that these are the best and only potential extraterrestrial sources of lithium known at the moment. The need to obtain raw materials where they are demanded results directly from the economy. It can be assumed that even the very expensive process of extracting lithium from common rocks on Mars or the Moon will be cheaper than transporting it from Earth. Until lithium-rich rocks or lithium-rich brines are found, this is the only possible source of this metal outside the Earth.

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