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Izotopová geochemie – izotopy B

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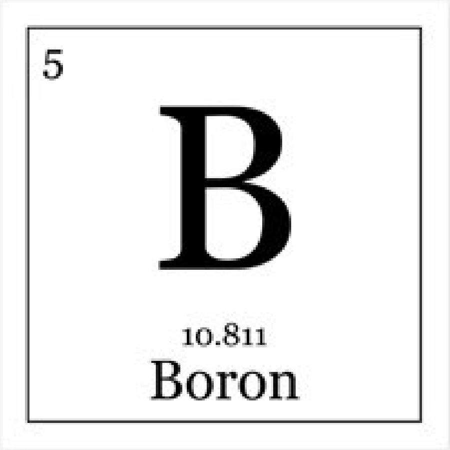
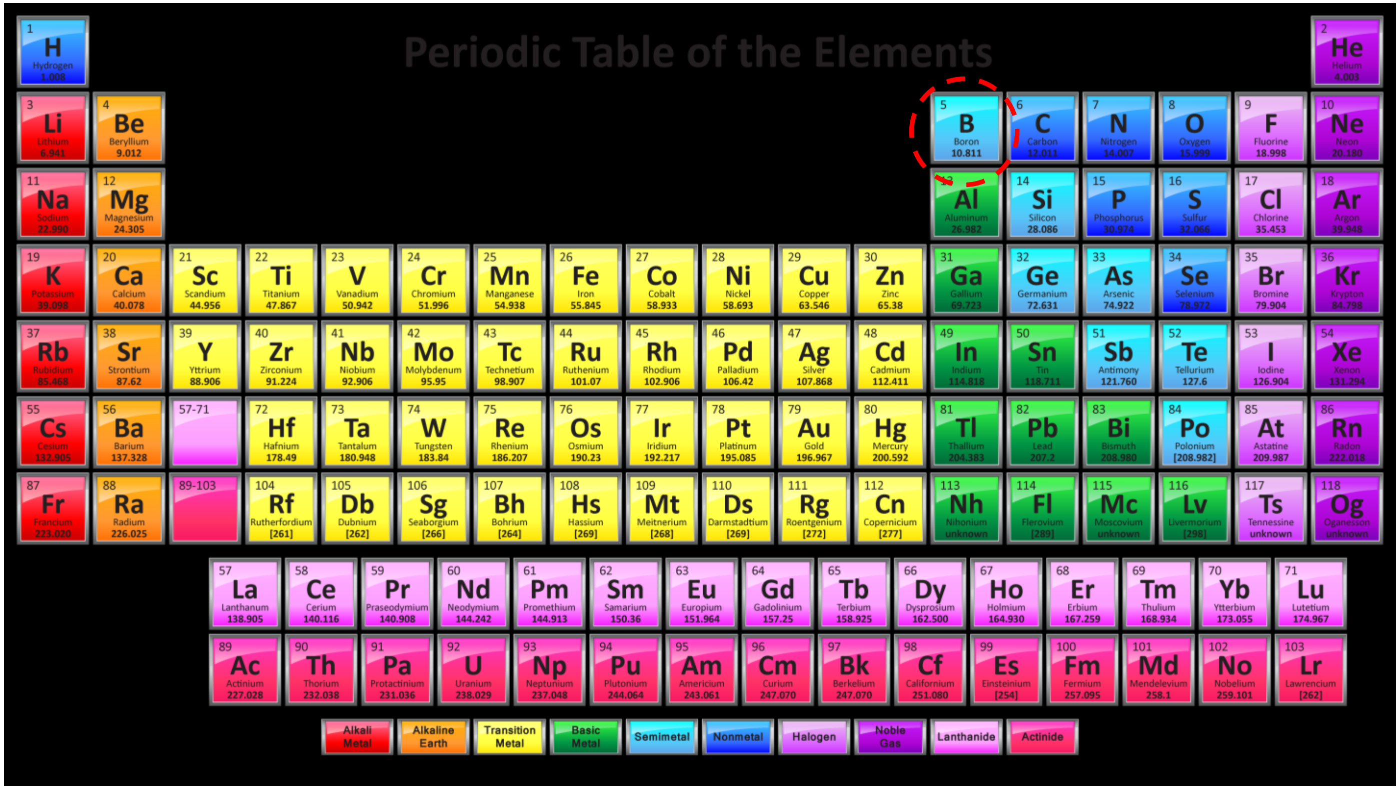


Bor

Turmalín (skoryl) – $NaFe^{2+}_3Al_6(BO_3)_3Si_6O_{18}(OH)_4$
Muskovit – $KAl_2(Si_3Al)O_{10}(OH,F)_2$

Bor

- Bor (též bór), chemická značka B, (lat. *Borum*) je 5. nejlehčím prvkem. Vyskytuje se ve dvou modifikacích – amorfní a kovové. Kovová modifikace patří mezi velmi tvrdé látky.



Periodic Table of the Elements

1 H Hydrogen 1.008																	2 He Helium 4.003
3 Li Lithium 6.941	4 Be Beryllium 9.012											5 B Boron 10.811	6 C Carbon 12.011	7 N Nitrogen 14.007	8 O Oxygen 15.999	9 F Fluorine 18.998	10 Ne Neon 20.180
11 Na Sodium 22.990	12 Mg Magnesium 24.305											13 Al Aluminum 26.982	14 Si Silicon 28.086	15 P Phosphorus 30.974	16 S Sulfur 32.066	17 Cl Chlorine 35.453	18 Ar Argon 39.948
19 K Potassium 39.098	20 Ca Calcium 40.078	21 Sc Scandium 44.956	22 Ti Titanium 47.867	23 V Vanadium 50.942	24 Cr Chromium 51.996	25 Mn Manganese 54.938	26 Fe Iron 55.845	27 Co Cobalt 58.933	28 Ni Nickel 58.693	29 Cu Copper 63.546	30 Zn Zinc 65.38	31 Ga Gallium 69.723	32 Ge Germanium 72.631	33 As Arsenic 74.922	34 Se Selenium 78.972	35 Br Bromine 79.904	36 Kr Krypton 84.798
37 Rb Rubidium 85.468	38 Sr Strontium 87.62	39 Y Yttrium 88.906	40 Zr Zirconium 91.224	41 Nb Niobium 92.906	42 Mo Molybdenum 95.95	43 Tc Technetium 98.907	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.906	46 Pd Palladium 106.42	47 Ag Silver 107.868	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Sn Tin 118.711	51 Sb Antimony 121.760	52 Te Tellurium 127.6	53 I Iodine 126.904	54 Xe Xenon 131.294
55 Cs Cesium 132.905	56 Ba Barium 137.328	57-71	72 Hf Hafnium 178.49	73 Ta Tantalum 180.948	74 W Tungsten 183.84	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.217	78 Pt Platinum 195.085	79 Au Gold 196.967	80 Hg Mercury 200.592	81 Tl Thallium 204.383	82 Pb Lead 207.2	83 Bi Bismuth 208.980	84 Po Polonium [208.982]	85 At Astatine 209.987	86 Rn Radon 222.018
87 Fr Francium 223.020	88 Ra Radium 226.025	89-103	104 Rf Rutherfordium [261]	105 Db Dubnium [262]	106 Sg Seaborgium [266]	107 Bh Bohrium [264]	108 Hs Hassium [269]	109 Mt Meitnerium [268]	110 Ds Darmstadtium [269]	111 Rg Roentgenium [272]	112 Cn Copernicium [277]	113 Nh Nihonium unknown	114 Fl Flerovium [289]	115 Mc Moscovium unknown	116 Lv Livermorium [298]	117 Ts Tennessine unknown	118 Og Oganesson unknown
		57 La Lanthanum 138.905	58 Ce Cerium 140.116	59 Pr Praseodymium 140.908	60 Nd Neodymium 144.242	61 Pm Promethium 144.913	62 Sm Samarium 150.36	63 Eu Europium 151.964	64 Gd Gadolinium 157.25	65 Tb Terbium 158.925	66 Dy Dysprosium 162.500	67 Ho Holmium 164.930	68 Er Erbium 167.259	69 Tm Thulium 168.934	70 Yb Ytterbium 173.055	71 Lu Lutetium 174.967	
		89 Ac Actinium 227.028	90 Th Thorium 232.038	91 Pa Protactinium 231.036	92 U Uranium 238.029	93 Np Neptunium 237.048	94 Pu Plutonium 244.064	95 Am Americium 243.061	96 Cm Curium 247.070	97 Bk Berkelium 247.070	98 Cf Californium 251.080	99 Es Einsteinium [254]	100 Fm Fermium 257.095	101 Md Mendelevium 258.1	102 No Nobelium 259.101	103 Lr Lawrencium [262]	

Alkali Metal | Alkaline Earth | Transition Metal | Basic Metal | Semimetal | Nonmetal | Halogen | Noble Gas | Lanthanide | Actinide

Bor

- Název bor je odvozen od minerálu, ze kterého byl v r. 1808 izolován.

- **Borax**, $Na_2B_4O_7 \cdot 10H_2O$ (tetraboritan sodný dekahydrát), evaporit, název pochází z arabského buraq – bílý.

- B vázán na borosilikáty: minerály ze sk. turmalínu (~3 hm. % B), světlé slídy (např. boromuskovit; ~2,8 hm. % B).

- Přírodní bor ($_5B$) obsahuje cca **19,9 %** stabilního izotopu ^{10}**B** (lehký B s 5 neutrony v jádře) a **80,1 %** stabilního izotopu ^{11}**B** (těžký B se 6 neutrony v jádře).

Bor – frakcionace

- Velký rozdíl mezi váhou izotopů ^{10}B and ^{11}B může vést k významné frakcionaci izotopů B díky řadě geologických procesů.

- Frakcionace izotopů B mezi taveninou/fluidy a minerální fází závisí na stupni koordinace (velikosti koordinačního čísla) mezi B-O a na teplotě (matematický model - Rayleigh equation).

- B může v různých fázích vystupovat v trigonální a tetragonální koordinaci s kyslíkem ($^{[3]}r = 0{,}01$Å, $^{[4]}r = 0{,}11$Å).

- Lehčí izotop **^{10}B** je přednostně zabudováván do fáze s vyšším koordinačním číslem, zatímco **^{11}B** preferuje fázi s nižším stupněm koord.

- **Turmalín preferuje ^{11}B** ($^{[3]}$B; výjimečně $^{[4]}$B); **muskovit preferuje ^{10}B** ($^{[4]}$B); metamorfní fluida přednostně odnášejí **^{11}B**; vodné/hydrotermální roztoky [nízké pH $B(OH)_3$ vs. vysoké pH $B(OH)_4$]

Bor

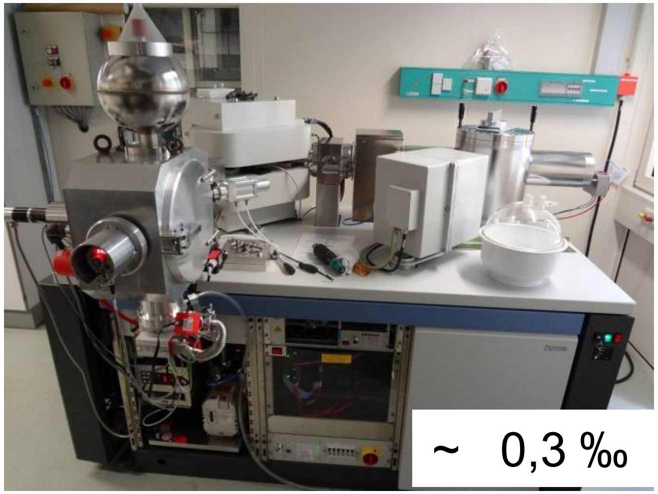
$$\delta^{11}\mathrm{B}\ (\text{‰}) = \left[\frac{(^{11}\mathrm{B}/^{10}\mathrm{B})_{\mathrm{vzorek}}}{(^{11}\mathrm{B}/^{10}\mathrm{B})_{\mathrm{SRM\ 951}}}\right] - 1\times10^{3}$$

SRM 951 standard
(Searles Lake borax)

Searles Lake, Mohavská poušť, Californie

Stanovení izotopového složení B

- Chemická separace B pomocí ionexu (k rozkladu vzorku nutné tavení s K_2CO_3) a následné stanovení izotopového složení B pomocí
  - 1) multikolektorového hmotnostního spektrometru s indukčně vázaným plazmatem (**MC-ICP-MS**; jako B^+ ionty).
  - 2) hmotové spektrometrie s termální ionizací (TIMS): **N-TIMS** s BO^{2-} ionty
    P-TIMS s Cs_2BO^{2+} ionty

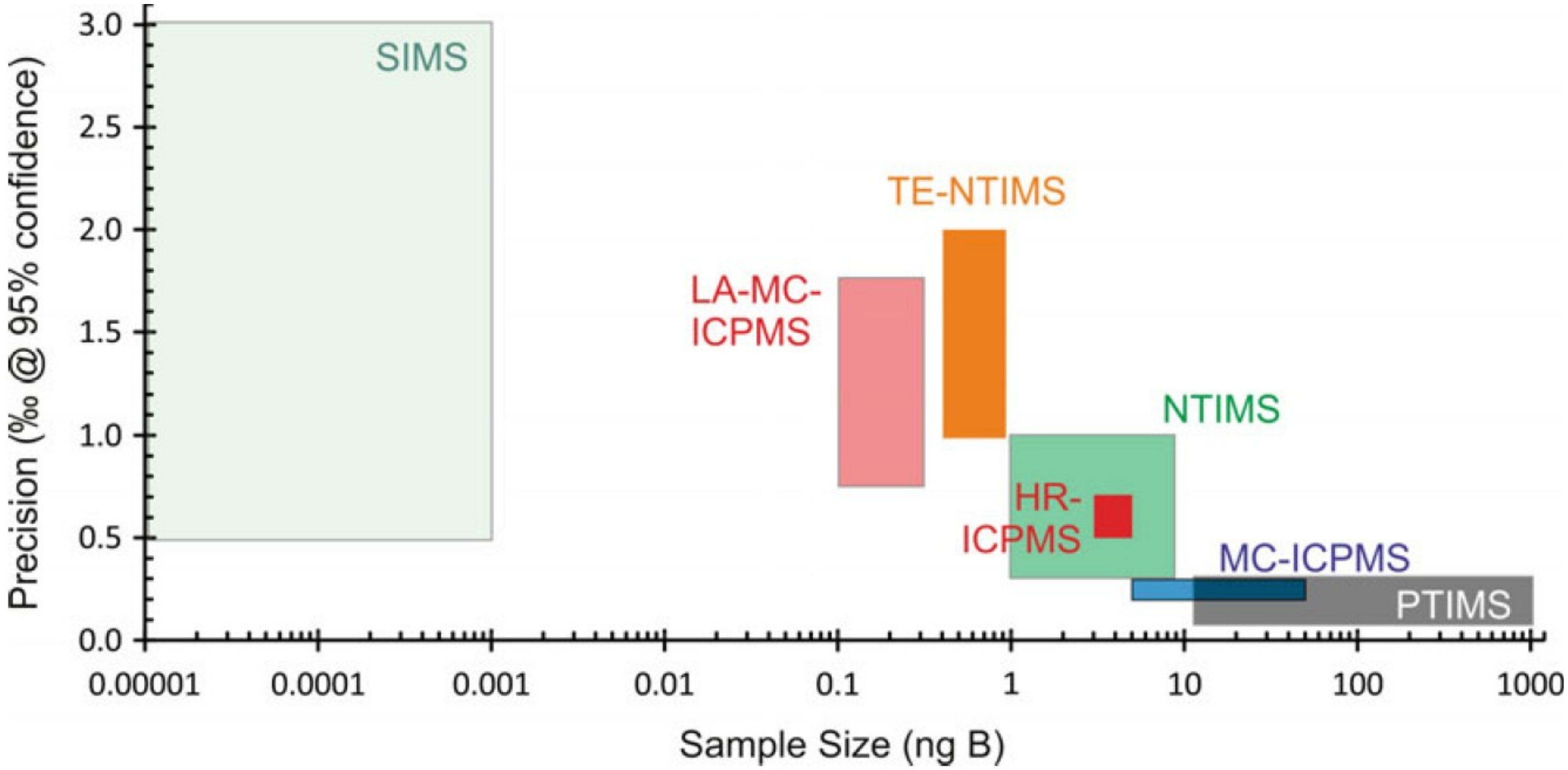


~ 0,3 ‰

- *In situ* analýza minerálu s B pomocí **SIMS** (hmotnostní spektrometrie sekundárních iontů - B^+; ostřelování primárními ionty $^{16}O^-$)

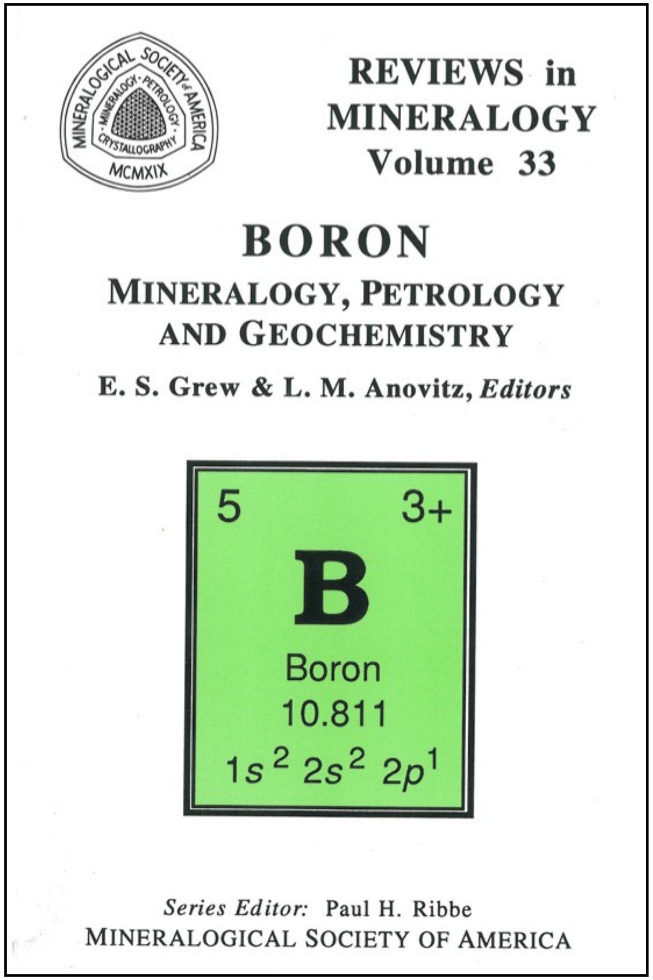
~ 1 ‰

Stanovení izotopového složení B



Základní literatura k izotopové geochemii B

Grew, E. S., **Anovitz**, L. M. eds. 1996, 2002. *Mineralogical Society of America*.



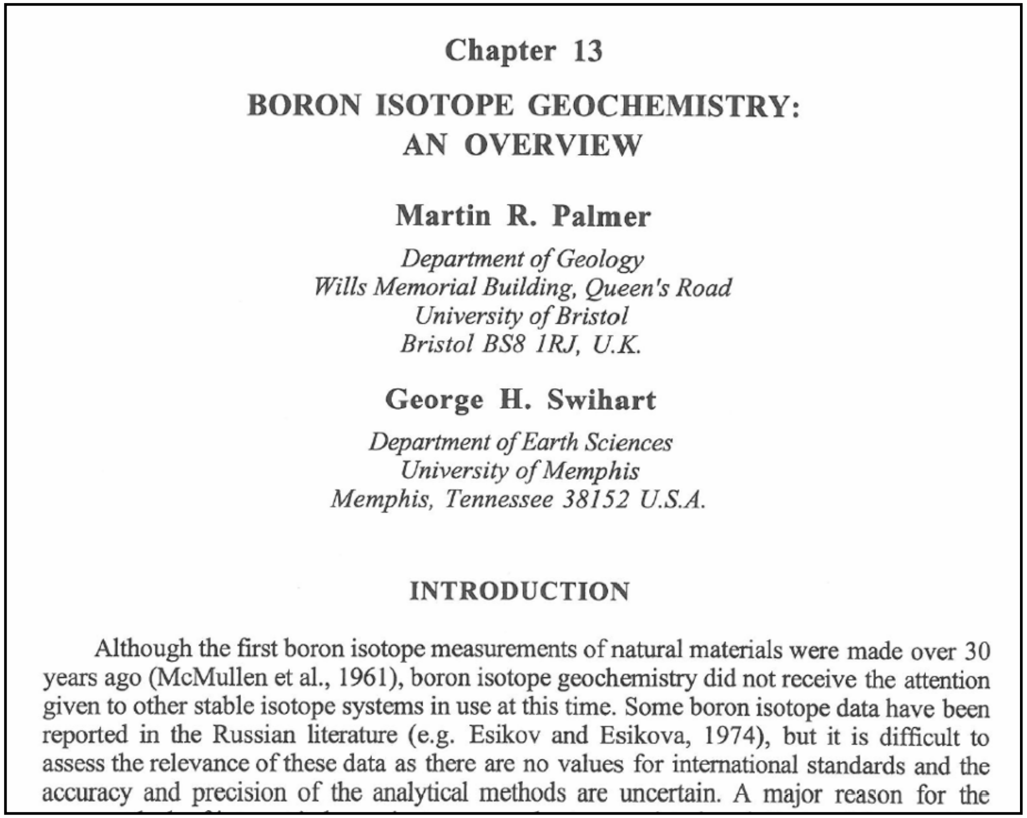
REVIEWS in
MINERALOGY
Volume 33

BORON
MINERALOGY, PETROLOGY
AND GEOCHEMISTRY

E. S. Grew & L. M. Anovitz, *Editors*

5 3+
B
Boron
10.811
$1s^2\ 2s^2\ 2p^1$

Series Editor: Paul H. Ribbe
MINERALOGICAL SOCIETY OF AMERICA



Chapter 13

BORON ISOTOPE GEOCHEMISTRY:
AN OVERVIEW

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INTRODUCTION

Although the first boron isotope measurements of natural materials were made over 30 years ago (McMullen et al., 1961), boron isotope geochemistry did not receive the attention given to other stable isotope systems in use at this time. Some boron isotope data have been reported in the Russian literature (e.g. Esikov and Esikova, 1974), but it is difficult to assess the relevance of these data as there are no values for international standards and the accuracy and precision of the analytical methods are uncertain. A major reason for the

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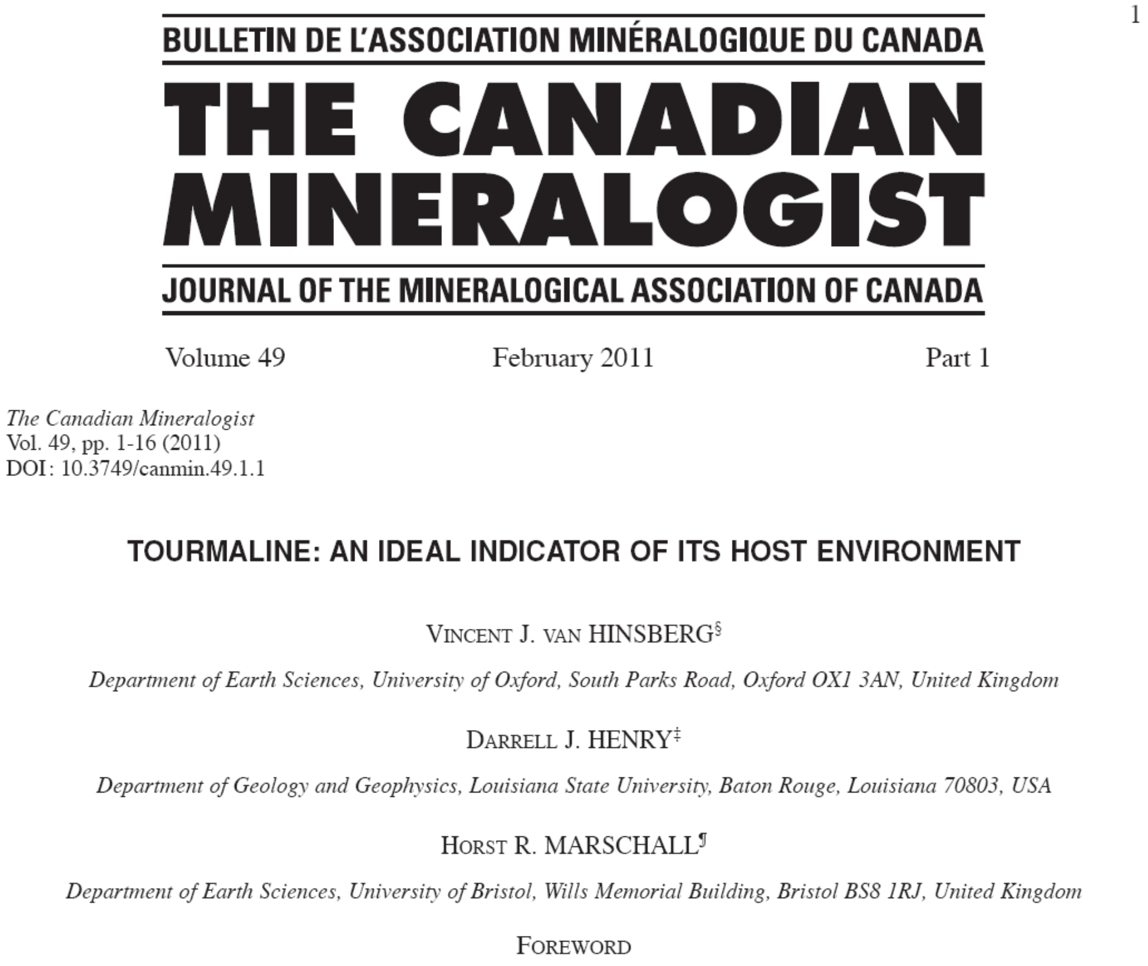

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TOURMALINE: AN IDEAL INDICATOR OF ITS HOST ENVIRONMENT

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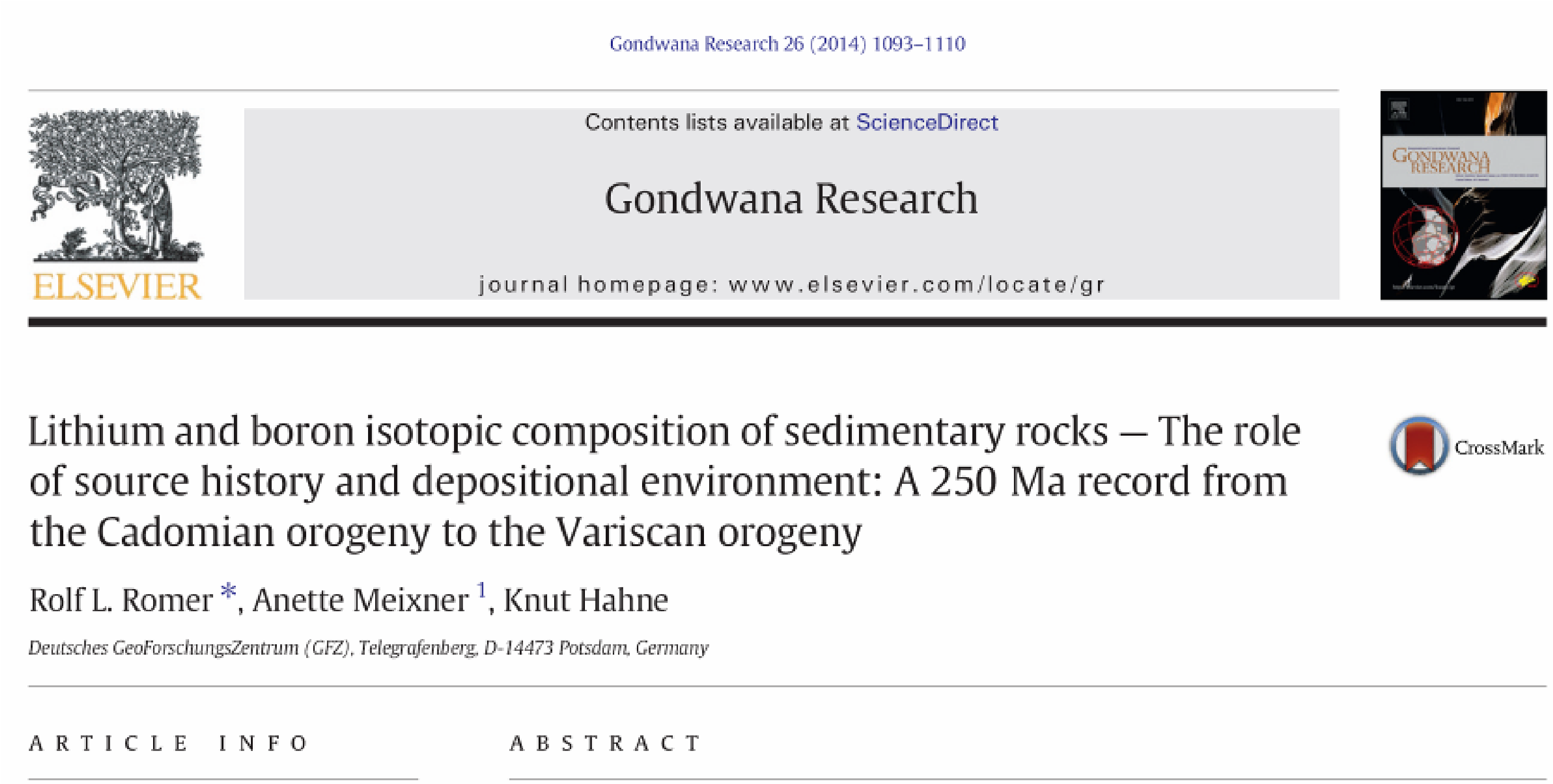
FOREWORD

Základní literatura k izotopové geochemii B



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Lithium and boron isotopic composition of sedimentary rocks — The role of source history and depositional environment: A 250 Ma record from the Cadomian orogeny to the Variscan orogeny

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A R T I C L E I N F O

A B S T R A C T

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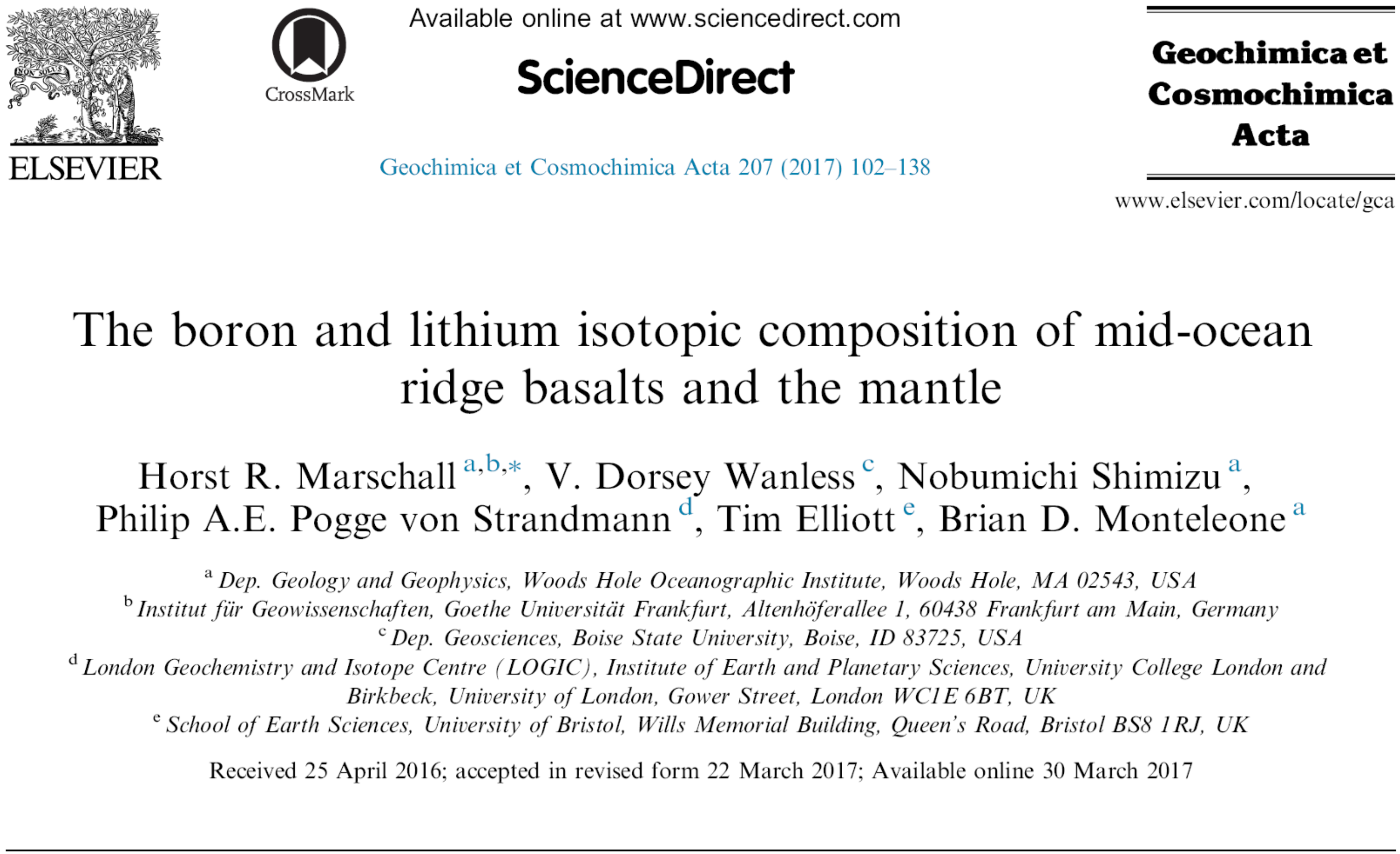

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The boron and lithium isotopic composition of mid-ocean ridge basalts and the mantle

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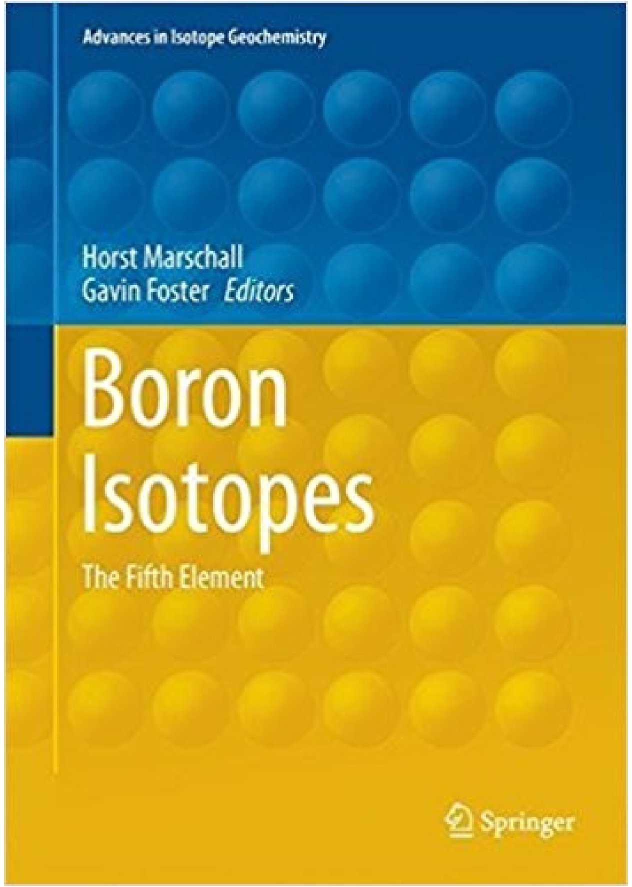
Marschall, Horst, **Foster**, Gavin eds. 2018. *Springer International Publishing*.



Advances in Isotope Geochemistry

Horst Marschall
Gavin Foster *Editors*

Boron
Isotopes

The Fifth Element

Springer

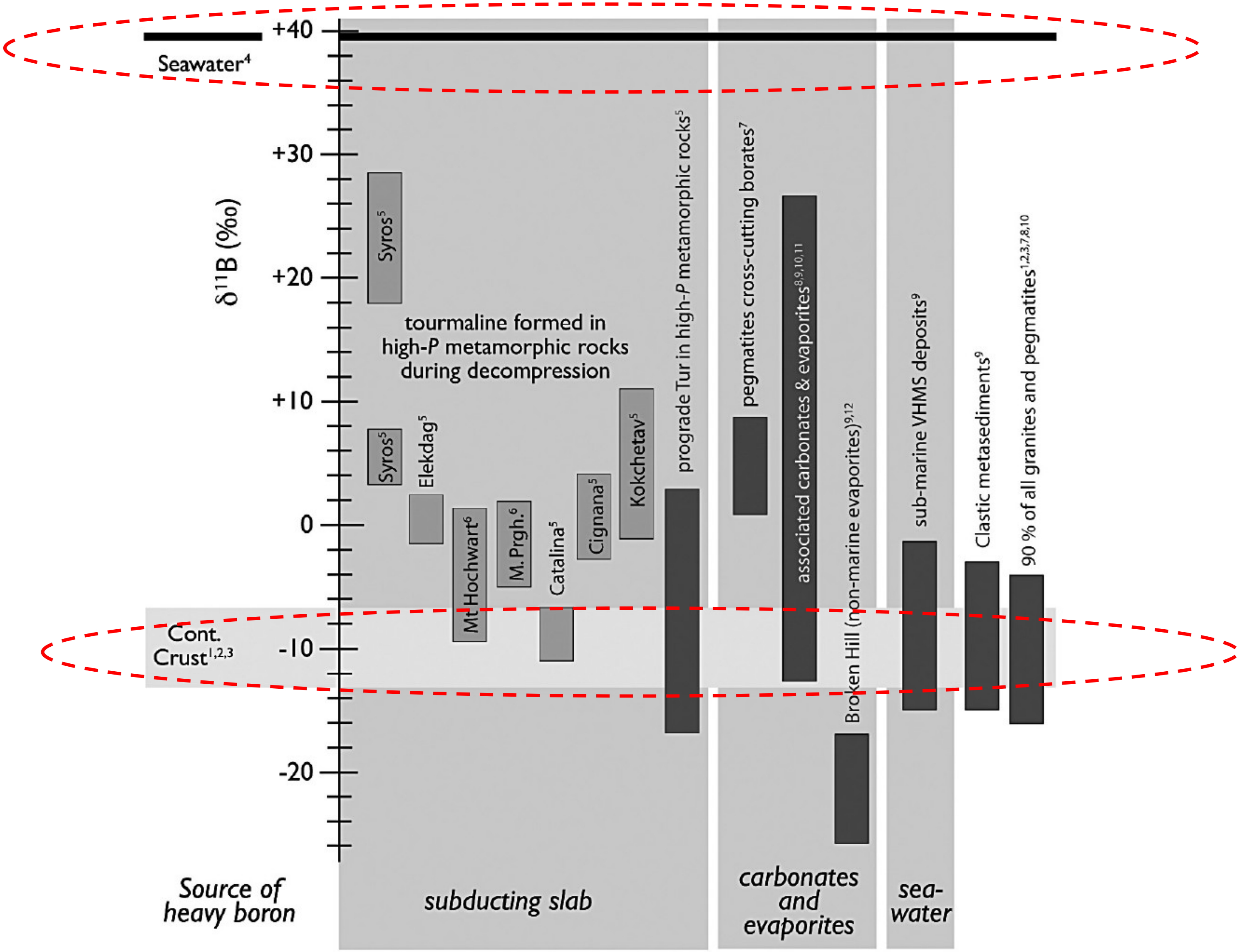
Boron Isotope Analysis of Geological Materials 2

Gavin L. Foster, Horst R. Marschall and Martin R. Palmer

Abstract
Over the last twenty years applications of the boron isotope system have expanded from the analysis of boron-rich phases (e.g., tourmaline, borates) to include other materials with low B concentrations (e.g., carbonates, basaltic glass). The accurate and precise determination of the boron isotopic composition of geological materials is however a difficult task, particularly for those where boron is present in low-concentration. For solution methods, this difficulty arises principally from the near ubiquitous level of boron contamination in most standard clean laboratories, the light mass of the element, the occurrence of only two stable isotopes, and the large mass difference between them. For in situ approaches, such as secondary-ion mass spectrometry, additional difficulties arise from the restricted availability of well-characterized reference materials, from surface contamination, from limited precision in low-concentration samples, and limitations in reproducibility in high-concentration samples that may partly arise from small-scale heterogeneities in the analyzed materials. Nevertheless, a variety of novel techniques, strategies and methodologies have been developed over the past two decades to meet these challenges. We describe here some of these developments and focus on those that we feel are going to play a major role in the growing use of the boron isotope system in the earth and planetary sciences in decades to come. AQ1

Keywords
■■■ AQ2

Izotopové složení rezervoárů B



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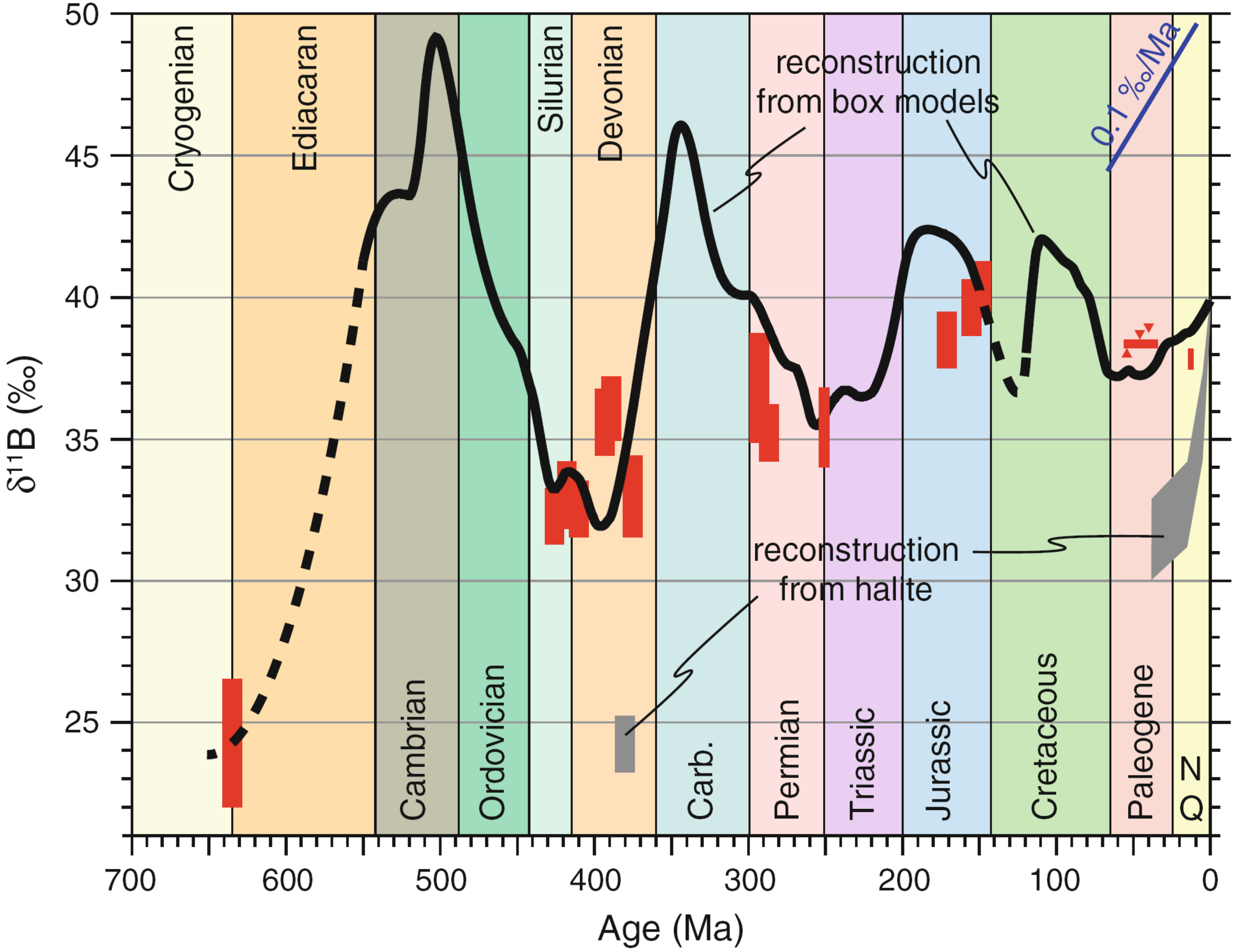
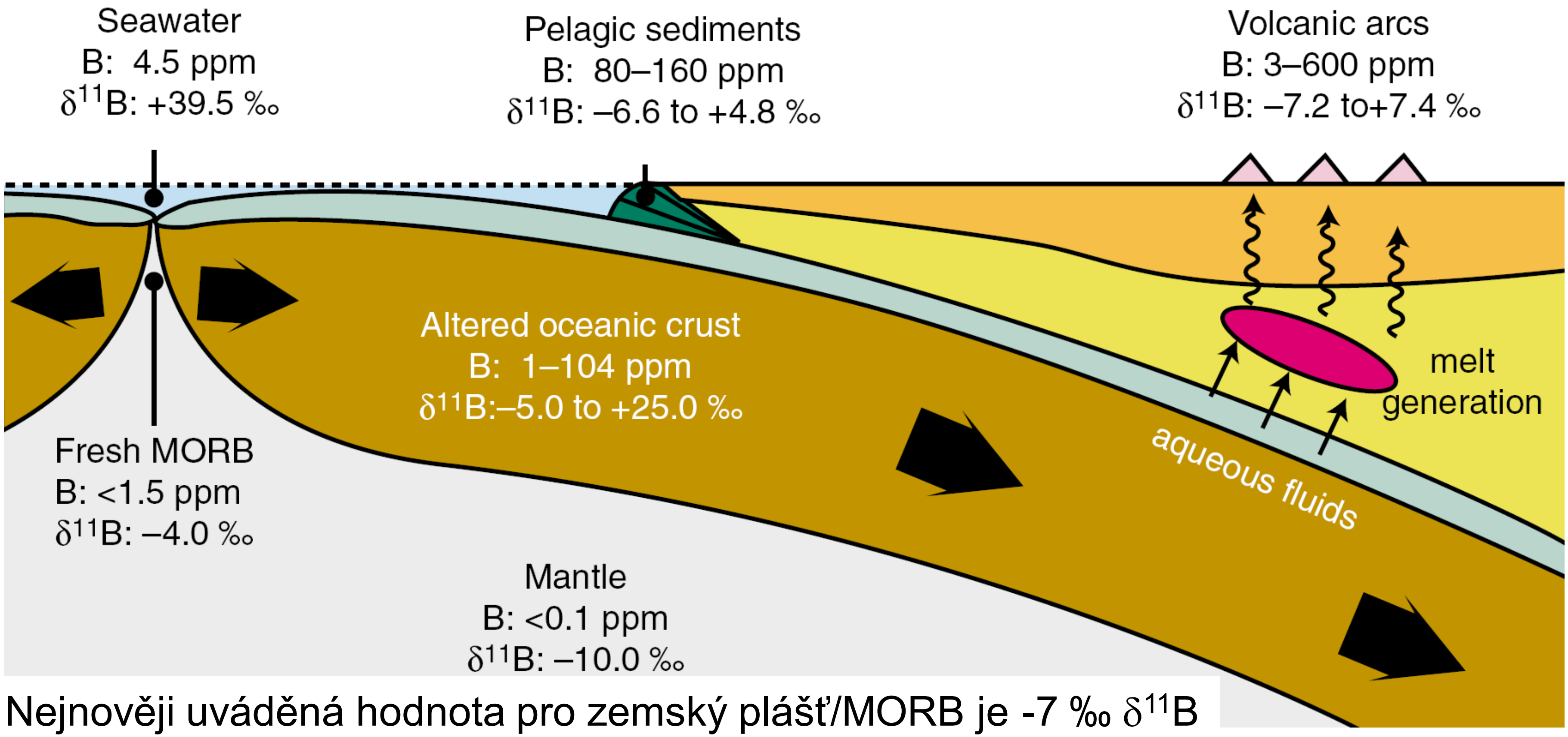


Izotopové složení rezervoárů B

Adsorpce $^{10}\mathrm{B(OH)}_4^-$ na marinní jílové minerály, biogenní kalcit a alterovanou oc. kůru



Seawater
B: 4.5 ppm
δ^{11}B: +39.5 ‰

Pelagic sediments
B: 80–160 ppm
δ^{11}B: –6.6 to +4.8 ‰

Volcanic arcs
B: 3–600 ppm
δ^{11}B: –7.2 to+7.4 ‰

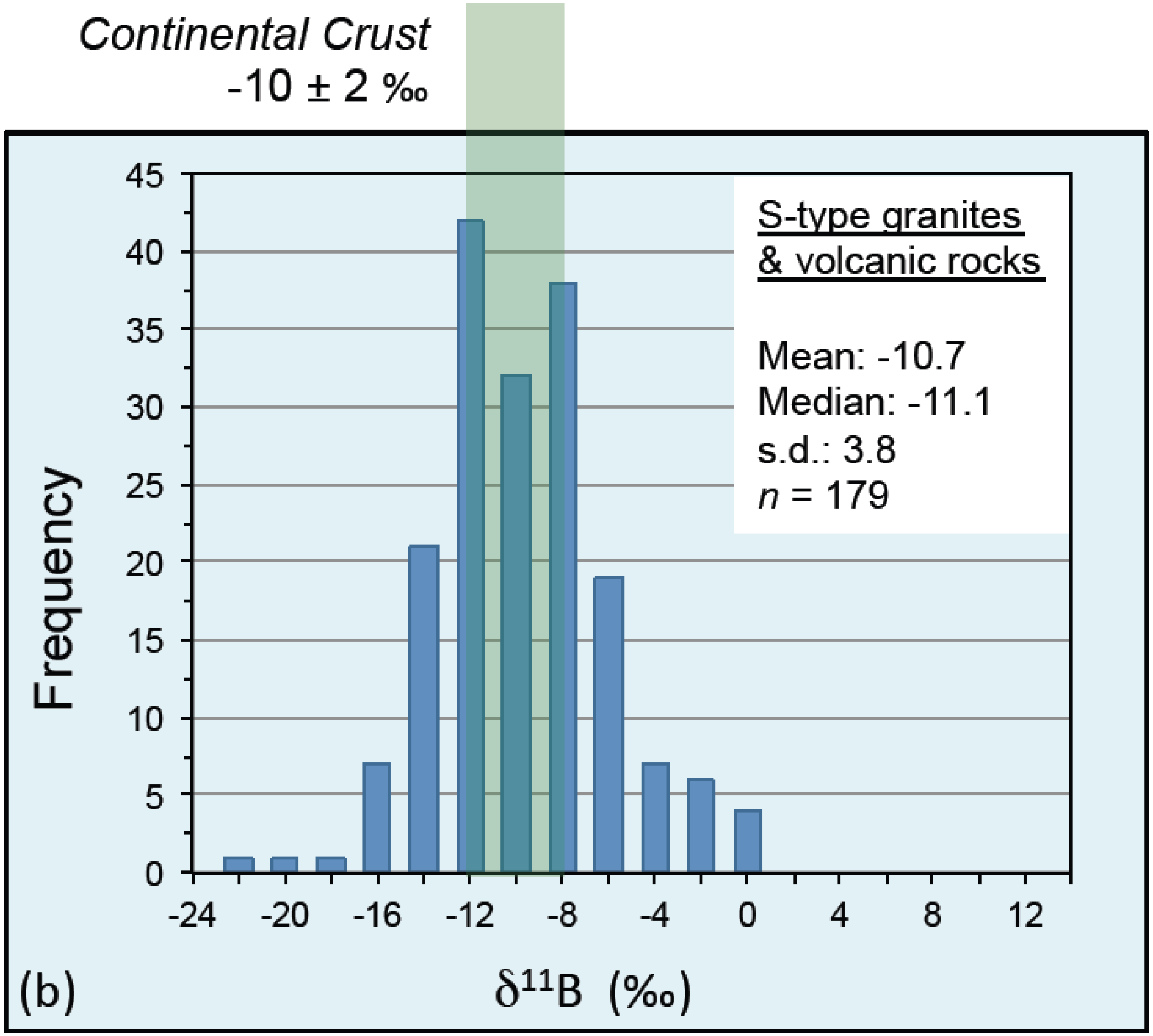
Altered oceanic crust
B: 1–104 ppm
δ^{11}B:–5.0 to +25.0 ‰

Fresh MORB
B: <1.5 ppm
δ^{11}B: –4.0 ‰

Mantle
B: <0.1 ppm
δ^{11}B: –10.0 ‰

Nejnověji uváděná hodnota pro zemský plášť/MORB je -7 ‰ δ^{11}B

Izotopové složení rezervoárů B



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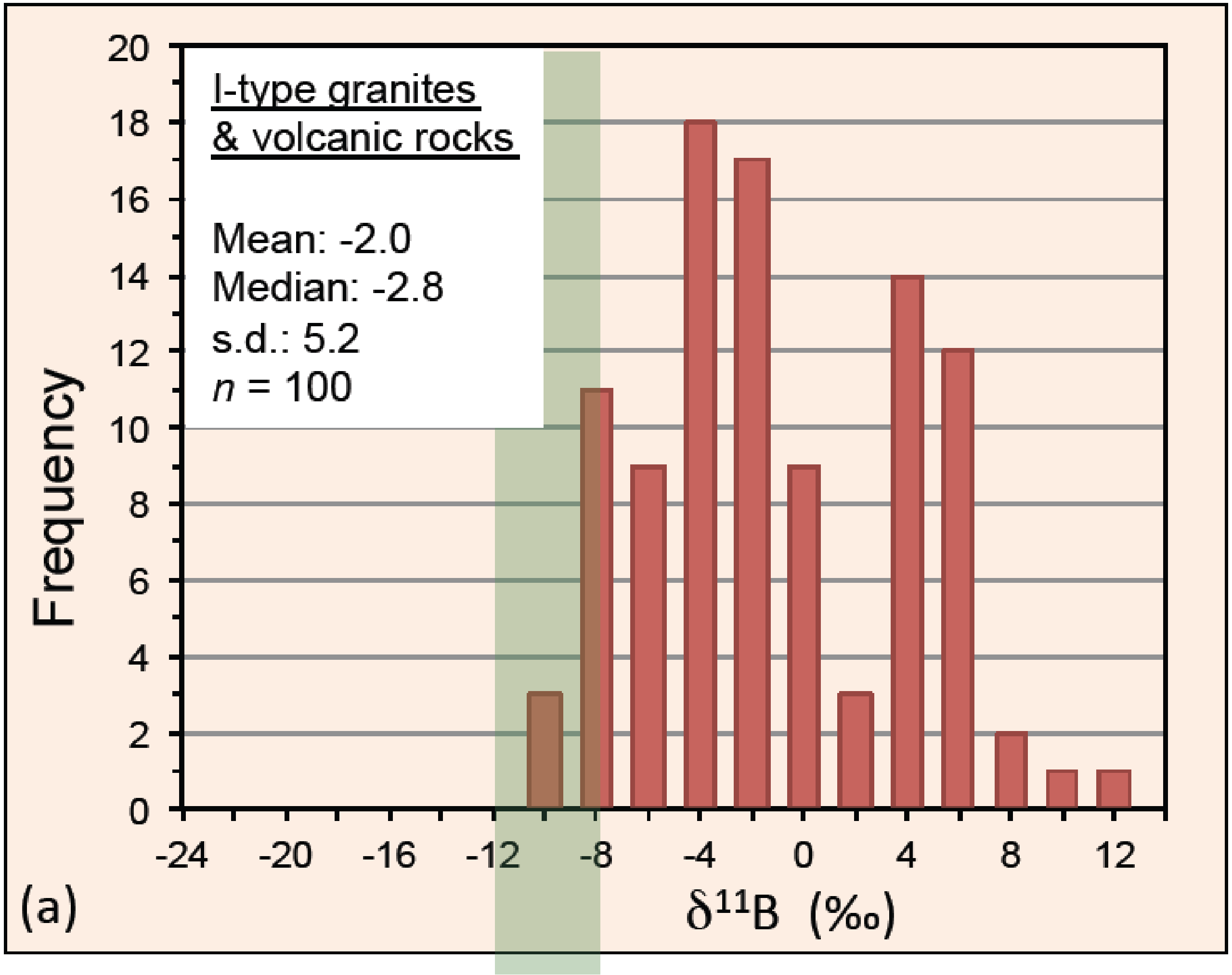

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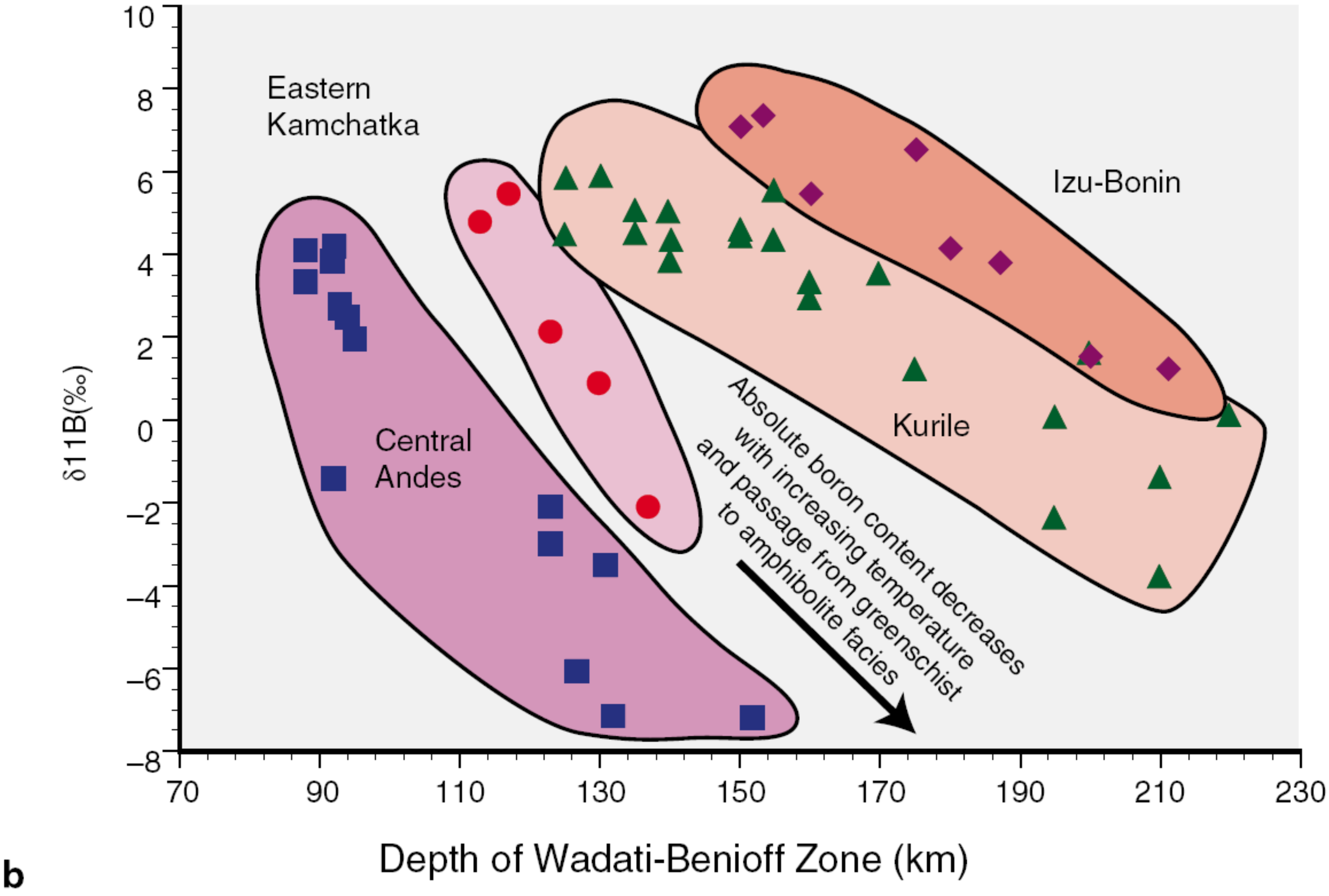
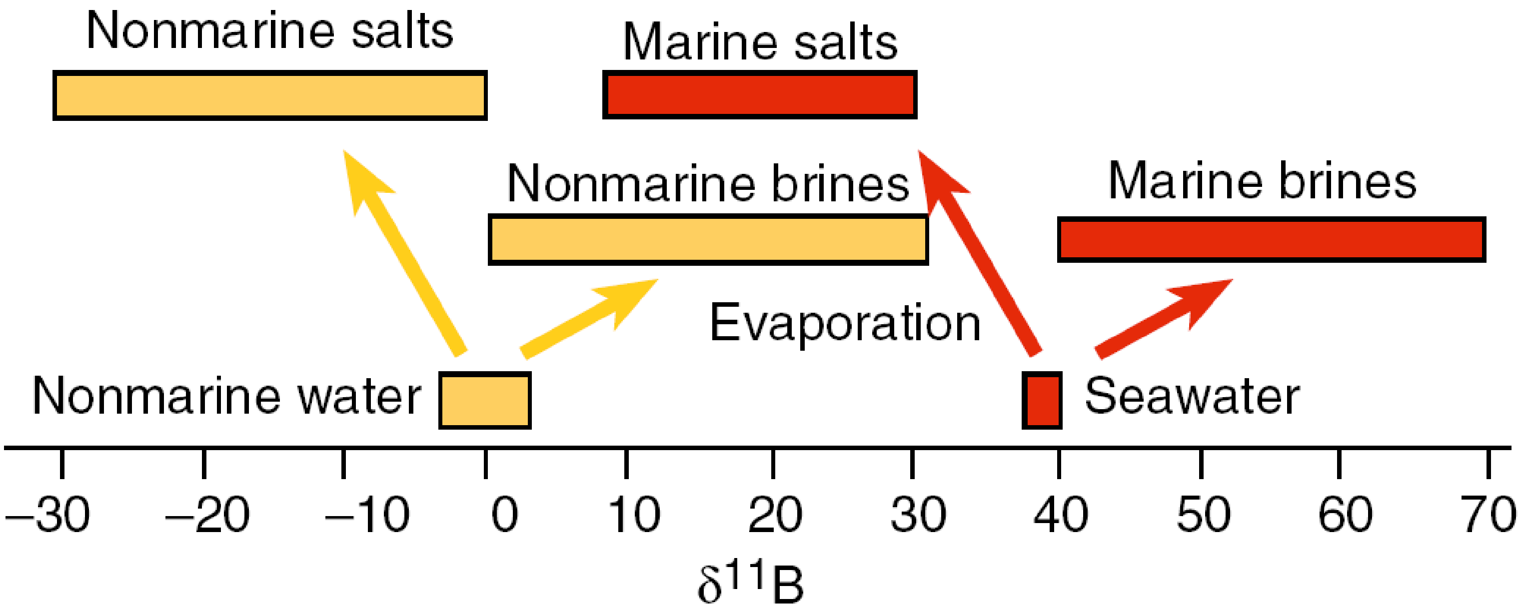


Izotopové složení rezervoárů B

V průběhu evaporace je $^{10}B(OH)_4^-$ přednostně zavazován do evaporitů (karbonáty, sulfáty) a reziduální solanky jsou obohacovány o ^{11}B (až +70 ‰ $\delta^{11}B$).



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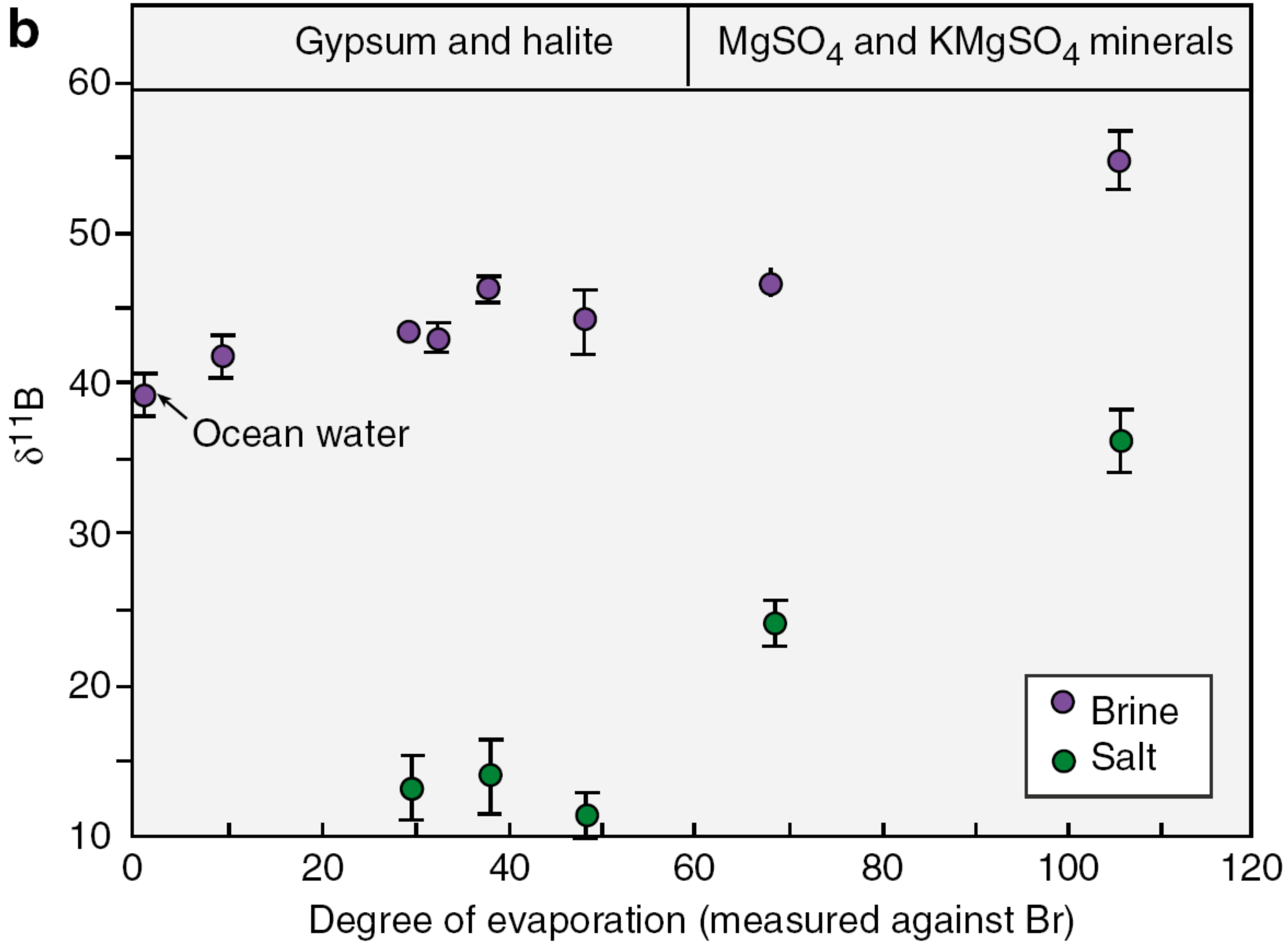

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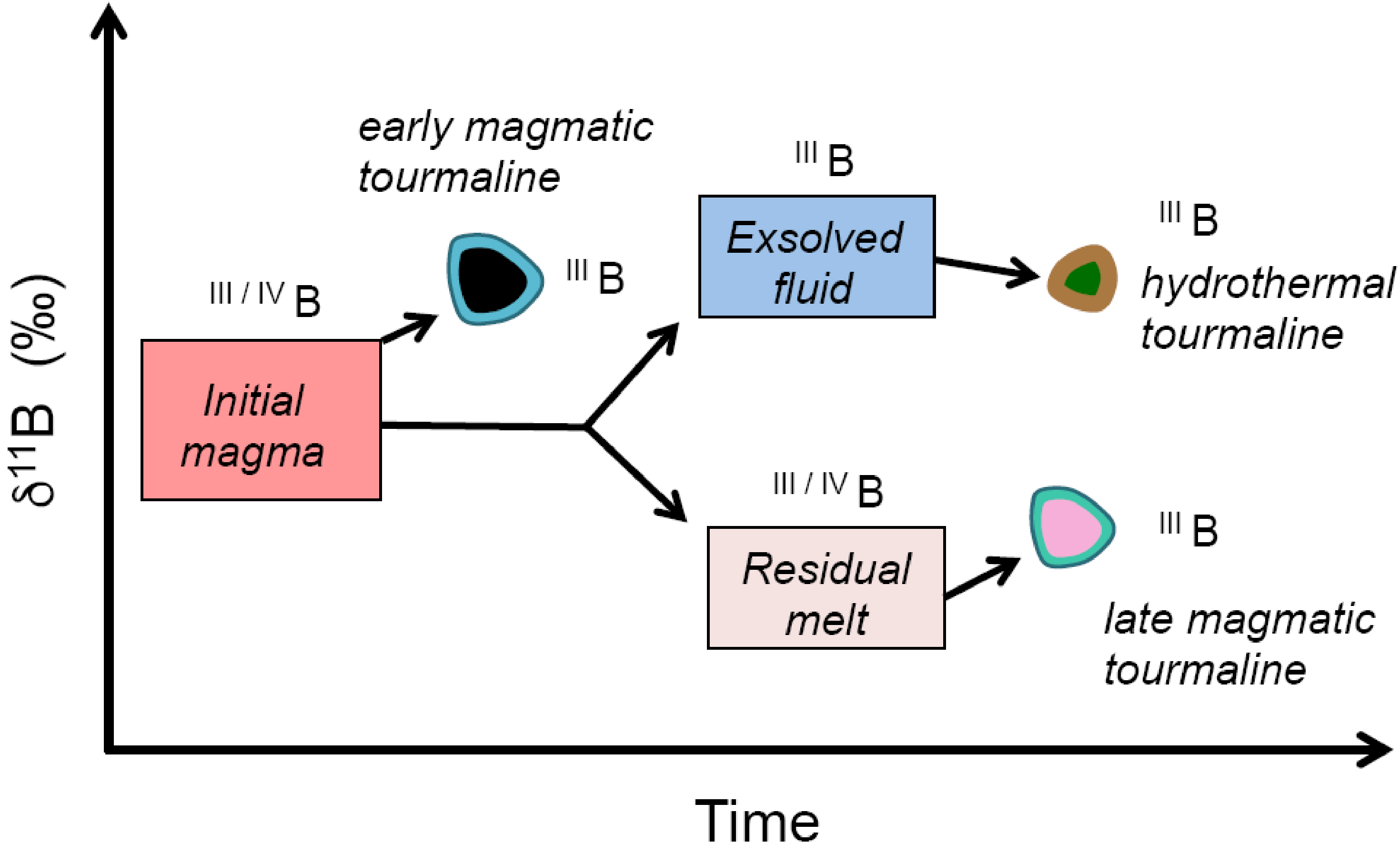

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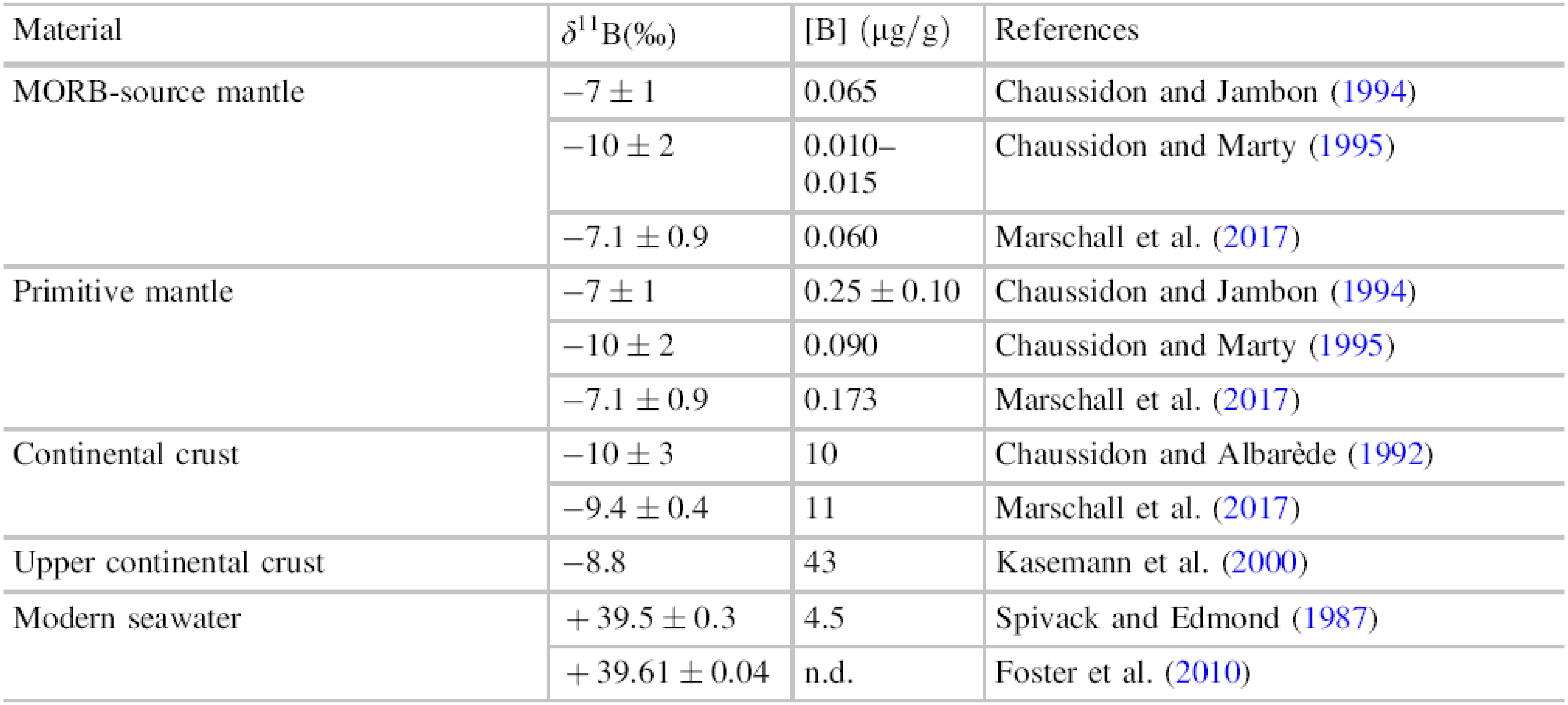

Material	δ^{11}B(‰)	[B] (µg/g)	References
MORB-source mantle	−7 ± 1	0.065	Chaussidon and Jambon (1994)
	−10 ± 2	0.010–0.015	Chaussidon and Marty (1995)
	−7.1 ± 0.9	0.060	Marschall et al. (2017)
Primitive mantle	−7 ± 1	0.25 ± 0.10	Chaussidon and Jambon (1994)
	−10 ± 2	0.090	Chaussidon and Marty (1995)
	−7.1 ± 0.9	0.173	Marschall et al. (2017)
Continental crust	−10 ± 3	10	Chaussidon and Albarède (1992)
	−9.4 ± 0.4	11	Marschall et al. (2017)
Upper continental crust	−8.8	43	Kasemann et al. (2000)
Modern seawater	+ 39.5 ± 0.3	4.5	Spivack and Edmond (1987)
	+ 39.61 ± 0.04	n.d.	Foster et al. (2010)

Izotopové složení rezervoárů B