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Absence of extraterrestrial ^{3}He in Permian–Triassic age sedimentary rocks

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Abstract

Helium concentration and isotopic composition were measured in a suite of samples across the Permian–Triassic boundary at Opal Creek, Canada, to determine whether high extraterrestrial helium concentrations are associated with a possible extinction-inducing impact event at this time. No extraterrestrial ^{3}He was detected, implying that neither fullerene-hosted nor IDP-hosted He is present at or near the boundary. This observation is consistent with similar studies of some Permian–Triassic sections, but contrasts sharply with reports of both fullerene- and IDP-hosted extraterrestrial ^{3}He at other sections.

Step-heat experiments indicate rapid diffusion of extraterrestrial helium from sediments heated to temperatures above ~70 °C. Given the likelihood of burial and associated heating in Permian–Triassic age rocks, the initially unexpected absence of IDP-hosted ^{3}He likely indicates thermally induced diffusive loss. Indeed one of the key sections (Graphite Peak, Antarctica) from which extraterrestrial ^{3}He has been reported at and near the Permian–Triassic boundary has been sufficiently heated that the reported preservation of extraterrestrial helium, in both IDPs and fullerenes, is inexplicable. Recent contamination provides a plausible explanation for extraterrestrial ^{3}He in these samples.

While no extraterrestrial ^{3}He was detected at Opal Creek, there is a sharp increase in nucleogenic ^{3}He very close to or at the Permian–Triassic boundary. This presumably arises from the major lithologic change at this time, from cherts in the Permian to shales and siltstones in the Triassic. Increased nucleogenic ^{3}He is associated with increases in both lithium and organic carbon content into the Triassic. Either the production rate or the retention of this ^{3}He is higher in the shales and siltstones than in the cherts. Care must be taken to eliminate such artifacts before interpreting changes in ^{3}He concentration in terms of fluctuations in the delivery of ^{3}He from space.

Keywords: extraterrestrial helium; cosmic dust; Permian-Triassic boundary; fullerene

1. Introduction

Multiple lines of evidence have been presented in favor of an extraterrestrial impact associated with the Permian–Triassic (PT) mass extinction. In the 1990s, a small Ir anomaly and microspherules [1], and shocked quartz [2] were described at the PT boundary. More recently PT age sediments were reported to carry extraterrestrial noble gases in fullerenes and IDPs [3,4] as well as unaltered meteorite fragments [5]. In addition a possible impact crater in the Indian Ocean has been

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alleged to be of the appropriate age [6]. These observations have been very controversial. Some of the original observations were not confirmed in the same or in other PT sections [7,8], the identification of the PT boundary in relation to the fullerene spike is doubtful in at least one case [9], and the existence of the Indian Ocean impact crater and its reported PT age have been rejected [10–12]. Although a great deal of very suggestive data has been published on the topic, no incontrovertible evidence for a PT-age impact yet exists.

The presence of high concentrations of extraterrestrial ^{3}He in sediments coincident (or nearly so) with the PT boundary would support the proposed impact event. ^{3}He might be present trapped within fullerenes released directly from the impactor [3] or in interplanetary dust particles (IDPs) [4]. While IDPs accumulate from multiple sources and need not be indicative of a significant extraterrestrial event, an enhanced IDP flux may be associated with showers of long period comets [13] and with major collisions in the asteroid belt [14]. Both of these events raise the likelihood of a terrestrial impact, in some cases enormously so [15]. Thus elevated IDP-hosted ^{3}He coincident with the PT boundary would provide indirect support for the occurrence of an impact. One advantage of using ^{3}He as an impact tracer is that elevated levels associated with major solar system events can last for a few million years [13,14], making detection far easier than locating a single ejecta layer in a long stratigraphic sequence.

Here we present results of He isotopic analyses across a well-studied PT boundary section to assess the presence of fullerene- or IDP-hosted ^{3}He. This work complements similar studies at Meishan and Shangsi, China [8], and in the Austrian Alps [16].

2. Setting, samples, and methods

Helium isotopes were measured in sedimentary rocks from the Opal Creek PT section in western Canada described by Henderson [17]. This site records a deep-water outer shelf environment composed of cherts in the Upper Permian Ranger Canyon unit and shales and siltsones in the uppermost Permian and lowermost Triassic Sulphur Mountain formation. The PT boundary has been identified based on conodont stratigraphy; it is characterized by black pyrite-bearing shales that likely indicate deposition in an anoxic environment. The average sedimentation rate through the sampled interval is about 2 cm/kyr. Thirty-three samples ranging from ~5 m below the PT boundary to ~40 m above the boundary were analyzed for helium, representing about 2.5 Myr. The densest sampling (few cm spacing) was undertaken near the PT boundary, while sampling away from the boundary was at several meter spacing.

Initially the ~1/2 g samples were decarbonated with acetic acid and the residue centrifuged prior to analysis [18]. As shown in Table 1, these samples contained very little acetic acid-soluble material (~20%), so for the remaining samples this step was omitted. Two samples were subjected for 12 h to hot concentrated 2:1 HF–HCl and then dried to isolate helium in acid-insoluble residue prior to analysis. These samples were then fused in vacuum at 1300 °C to release helium. For one additional sample He was extracted by incremental step heating of 1 h duration per step using a resistance furnace. Temperature uncertainties on this experiment are estimated to be ±30 °C.

Table 1
Helium in Opal Creek samples

Sample	Position (cm)	^{3}He (fmol/g)	^{4}He (pmol/g)	^{3}He/^{4}He ($\times 10^8$)	Non-carbonate fraction
224	3915	0.00242	138.8	1.82	Whole rock (WR)
216	3115	0.01339	185.3	7.28	WR
192	1810	0.00797	138.7	5.74	WR
177	1003.5	0.01495	477.4	3.22	WR
176	983.5	0.01042	235.4	4.48	WR
173	850.5	0.00869	337.1	2.52	WR
166	423.5	0.01082	370.3	2.94	WR
161	310.5	0.01053	288.2	3.64	WR
121	175.5	0.00820	332.9	2.52	WR
44	116.75	0.01324	402.6	3.36	WR
62	90.5	0.00983	474.4	2.10	WR
7	49.5	0.00286	316.2	0.98	0.81
8	48.5	0.00302	226.4	1.40	0.82
9	47.5	0.00292	325.7	0.98	0.82
10	46	0.00358	486.6	0.70	0.86
11	44.5	0.00345	298.3	1.12	0.82
12	43	0.00351	341.8	0.98	0.84
13	40	0.00305	302.8	0.98	0.83
13	40	0.00911	401.8	2.24	WR
14	37.5	0.00838	370.9	2.24	0.83
15	36.5	0.00297	241.8	1.26	0.83
16	30.75	0.00348	266.0	1.26	0.83
17	29	0.00286	214.0	1.40	0.80
19	26.5	0.00315	234.8	1.40	0.83
20	24.25	0.00096	56.6	1.68	0.82
21	22	0.00285	229.3	1.26	0.82
22	17.5	0.00274	231.6	1.26	0.79
23	15	0.00129	90.7	1.40	0.73
1	−4	0.00122	365.5	0.28	0.85
201	−110	0.00074	27.0	2.80	WR
202	−200	0.00047	118.9	0.42	WR
204	−270	0.00162	375.8	0.42	0.92
206	−470	0.00781	268.3	2.94	WR
HF–HCl residue					
192	1810	ND	5.6	ND	Residue
216	3115	0.00100	20.5	4.9	Residue