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Research Advances

Carbon Isotope Excursions and Paleo-Oceanography of the Ordovician–Silurian Boundary Carbonate Rocks from the Xainza Area, Tibet

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Objective

The Ordovician–Silurian transitional period is a special time when the global paleo-environment changed greatly. It witnessed the first mass extinction as of Phanerozoic period and glaciations that occurred frequently at a large scale in a very short time, which has thus attracted much attention among geoscientists at home and abroad. The most complete and continuous development of Paleozoic strata occurs in the Xainza area, Tibet, which are dominated by carbonate sediments during the Ordovician-Silurian period and provide good materials for research on carbon isotopes. This work focused on the carbon isotope excursion of the Ordovician–Silurian marine carbonates in the Xainza area, Tibet, which is the key to studying the glaciations and mass extinction of the Ordovician–Silurian period of East Paleo-Tethys, as well as the changes of paleo-climate environment and paleo-ocean environment (Ren Ying et al., 2018).

Methods

The 5118 section, located at the side of Xainza–Xiongmei road, is 2.6 km northwest of Yongzhu village in Tibet. It is a representative section of Ordovician–Silurian marine carbonates in East Paleo-Tethys. This section has continuous strata and contains abundant biological fossils. Previous researches have analyzed the marine carbonates along this section and built a precise bio-stratum framework. It has thus become a perfect section for geochemistry research of carbonates. This section develops continuous strata, including the Upper Ordovician Gangmusang Formation, Lower–Middle Silurian Dewukaxia Formation and Middle–Upper Silurian Zhanongema Formation. Based on the paleontological identification of regional geological survey by Prof. Wang Chengyuan and Rong Jiayu from the Nanjing Institute of Geology and Palaeonotology, China Geological Survey, these formations can be divided into five periods, i.e., Katian, Hirnantian, Rhuddanian–Telychian, Sheinwoodian and Gorstian–Ludfordian. In this study, a total of 60 representative slightly weathered rock samples were collected, and a series of analysis including section identification, cathodeluminescence analysis, elemental geochemical analysis and isotope analysis.

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Results

The Ordovician–Silurian along the 5118 section consists of micrite limestone, crystalline dolomite and shale. The primary sedimentary structure is apparent with medium-thin laminar structure and smaller secondary veins, with dark or non-luminance cathodeluminescence features. The Mn/Sr ratio is <2, with an average of 0.86, and the Er/Nd ratio is not lower than 0.1. The $\delta^{13}C_{carb}$ ratio of the carbonates from the 5118 section ranges from −1.9‰ to 6‰, with an average of 1.4‰; the $\delta^{18}O$ ratio ranges from −6‰ to −10‰, with an average of −8.1‰, and the $\delta^{13}C_{org}$ ratio ranges from −24.10‰ to −28.80‰, with an average of −26.92‰ (Appendix 1). Based on the systematical analysis of carbon isotope of rocks from the 5118 section in the Xainza area, there are four significant carbon isotope excursions in the carbon isotope value curves. It is the first time that carbon isotope excursions have been observed in the Lhasa block of East Paleo-Tethys. Through analysis on other blocks, four significant carbon isotope excursions are ubiquitous, and the pattern, amplitude and form of the carbon isotope excursions are globally synchronous. The four significant carbon isotope excursions must be global events, and this section can serve as a carbon isotope reference section for the study of paleo-ocean evolution in Paleo-Tethys. These carbon isotope excursions are HICE, AICE, SICE and LICE, with amplitude of 1.8‰, 1.6‰, 5.1‰ and 6.3‰, respectively. Carbon burial factors of carbonates from the 5118 section

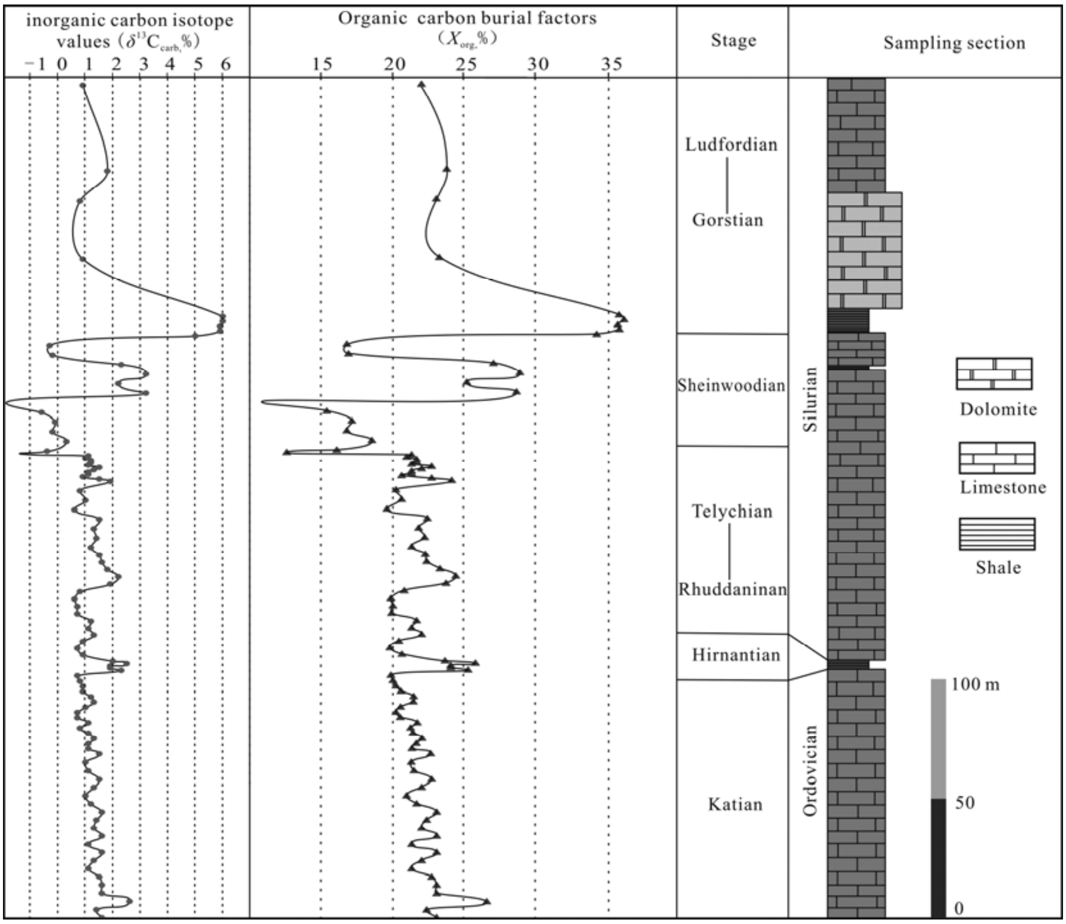

Fig. 1. Carbon isotope curves of carbonate rocks from the 5118 section, Xainza area.

are calculated based on the equations of carbon cycle theory, including (1) $F_w=F_{org}+F_{carb}$, (2) $F_w\delta_w= F_{carb}\delta_{carb}+F_{org}(\delta_{carb}+\Delta)$, and (3) $X_{org}=(\delta_{carb}-\delta_w)/\Delta$, wherein F_w is the input of carbon from weathering, F_{org} is sediment burial output as organic matter, F_{carb} is sediment burial output as carbonate mineral, δ_w is −5‰, and Δ represents the isotopic difference between organic matter and carbonate deposited from the ocean. The results show that there are five variations of the organic burial factors in the Ordovician–Silurian, and two variations in the Silurian have variation amplitude of larger than 25%. The organic burial factors vary between 11% and 36%, with an average of 22% (Appendix 1).

Conclusions

(1) During the Ordovician–Silurian period in the Tibet Plateau, the increase of the organic carbon is the cause of the carbon isotope positive excursions and heavy carbon isotope accumulations.

(2) Four obvious carbon isotope excursions of Ordovician-Silurian are identified in the Xainza area, Tibet, which is the key to research changes of paleo-climate environment and paleo-ocean environment during the Ordovician–Silurian period.

Acknowledgments

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Appendix 1 Carbon isotope values of carbonate rocks of the 5118 section

Sample number	Depth	Stratum	$\delta^{13}C_{carb}$ (%)	$\delta^{18}O_{carb}$ (%)	Organic carbon burial factors (%)	Sample number	Depth	Stratum	$\delta^{13}C_{carb}$ (%)	$\delta^{18}O_{carb}$ (%)	Organic carbon burial factors (%)
ZM (35)	56.67	Zhanongema Fm.	2.00	−4.00	0.25	GM (−27)	256.46	Dewukaxia Fm.	1.20	−8.50	0.21
ZM (34)	60.04	Zhanongema Fm.	0.90	−4.10	0.21	GM (−24)	265.81	Dewukaxia Fm.	1.80	−7.10	0.23
ZM (32)	96.38	Zhanongema Fm.	1.80	−3.20	0.24	GM (−22)	272.04	Dewukaxia Fm.	1.90	−6.80	0.24
ZM (31)	109.26	Zhanongema Fm.	0.80	−3.80	0.23	GM (−21)	275.16	Dewukaxia Fm.	0.80	−5.40	0.21
ZM (30)	133.78	Zhanongema Fm.	0.90	−4.80	0.23	GM (−19)	281.39	Dewukaxia Fm.	0.70	−6.50	0.20
ZM (29)	158.33	Dewukaxia Fm.	6.00	−4.50	0.36	GM (−17)	287.62	Dewukaxia Fm.	1.20	−5.90	0.22
ZM (28)	160.35	Dewukaxia Fm.	6.00	−4.30	0.36	GM (−15)	293.55	Dewukaxia Fm.	1.30	−8.00	0.22
ZM (27)	162.38	Dewukaxia Fm.	5.90	−4.40	0.36	GM (−13)	299.18	Dewukaxia Fm.	0.70	−7.00	0.20
ZM (26)	164.40	Dewukaxia Fm.	5.90	−5.20	0.36	GM (−12)	301.99	Dewukaxia Fm.	0.90	−7.20	0.21
ZM (25)	166.42	Dewukaxia Fm.	5.00	−5.90	0.34	GM (−11)	304.80	Dewukaxia Fm.	2.00	−10.20	0.24
ZM (24) −2	170.50	Dewukaxia Fm.	−0.30	−8.70	0.17	GM (1)	305.78	Dewukaxia Fm.	2.50	−11.50	0.26
ZM (24) −1	174.58	Dewukaxia Fm.	−0.20	−9.90	0.17	GM (2)	306.77	Dewukaxia Fm.	1.90	−11.70	0.24
ZM (24)	178.66	Dewukaxia Fm.	2.30	−16.70	0.27	GM (3)	307.75	Dewukaxia Fm.	1.90	−11.40	0.24
ZM (23)	182.74	Dewukaxia Fm.	3.20	−15.30	0.29	GM (4)	308.73	Dewukaxia Fm.	2.30	−11.30	0.25
ZM (24) Supp.	186.82	Dewukaxia Fm.	2.20	−16.60	0.25	GM (−10)	310.94	Gangmusang Fm.	0.70	−7.00	0.20
ZM (23) Supp.	190.90	Dewukaxia Fm.	3.20	−15.50	0.29	GM (−9)	313.16	Gangmusang Fm.	0.80	−6.90	0.20
ZM (22)	194.98	Dewukaxia Fm.	−1.90	−9.10	0.11	GM (−8)	315.37	Gangmusang Fm.	0.90	−7.10	0.20
ZM (21)	199.06	Dewukaxia Fm.	−0.60	−9.20	0.15	GM (−7)	317.58	Gangmusang Fm.	0.90	−7.20	0.21
ZM (18)	211.30	Dewukaxia Fm.	0.30	−8.50	0.19	GM (−4)	324.22	Gangmusang Fm.	1.00	−7.60	0.21
ZM (17)	215.38	Dewukaxia Fm.	−0.40	−13.70	0.16	GM (−1)	330.86	Gangmusang Fm.	1.10	−6.80	0.22
ZM (16)	216.38	Dewukaxia Fm.	−1.40	−10.30	0.13	GM (7)	337.50	Gangmusang Fm.	1.30	−7.70	0.22
ZM (14)	218.39	Dewukaxia Fm.	1.00	−8.70	0.21	GM (10)	344.14	Gangmusang Fm.	1.50	−8.20	0.23
ZM (12)	220.39	Dewukaxia Fm.	1.20	−8.50	0.22	GM (13)	354.88	Gangmusang Fm.	1.50	−8.30	0.23
ZM (09)	223.40	Dewukaxia Fm.	1.30	−8.40	0.22	GM (16)	365.23	Gangmusang Fm.	1.20	−7.40	0.22
ZM (07)	225.40	Dewukaxia Fm.	1.10	−9.10	0.21	GM (19)	375.58	Gangmusang Fm.	1.30	−8.70	0.22
ZM (06)	226.41	Dewukaxia Fm.	0.90	−9.90	0.21	GM (22)	385.93	Gangmusang Fm.	1.60	−8.50	0.23
ZM (04)	228.41	Dewukaxia Fm.	1.90	−8.50	0.24	GM (25)	396.28	Gangmusang Fm.	1.50	−8.80	0.23
ZM (03)	232.42	Dewukaxia Fm.	0.80	−8.30	0.20	GM (27)	403.18	Gangmusang Fm.	1.60	−8.10	0.23
ZM (01)	240.43	Dewukaxia Fm.	0.60	−8.20	0.20	GM (28)	406.63	Gangmusang Fm.	2.60	−8.00	0.27
GM (−29)	248.45	Dewukaxia Fm.	1.30	−6.80	0.22	GM (30)	413.53	Gangmusang Fm.	1.60	−7.70	0.23