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Isotopic dating of the Chengjiang Fauna-bearing horizon in Central Yunnan Province, China

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Abstract Twenty black shale samples, which are free from the influence of weathering, were collected from the Chengjiang Fauna-bearing horizon, central Yunnan Province, yielding a Pb-Pb isochron age of 534±60 Ma. Although this age is younger than both the Rb-Sr isochron age and ^{40}Ar-^{39}Ar age, it should represent the lower isotopic age limit of the Chengjiang Fauna.

Key words Chengjiang Fauna; lead isotope; isotopic dating; Yunnan Province

1 Introduction

Geochronologically, the Chengjiang Fauna is intermediate between the Ediacara Fauna of Australia and the Burgess Shale Fauna of Canada. Therefore, the study of the Chengjiang Fauna is of great significance in understanding the origin and evolution of animals in the early history of the Earth, but its precision dating has long been one of the problems concerned by many geological workers. As the Chengjiang Fauna occurs in the strongly weathered yellowish-green shales, the precision dating of this fauna has become a difficult problem. As a result, even up to now, no satisfactory isotopic age has yet been reported. In the past the Rb-Sr isochron dating method was employed for dating of the Chengjiang Fauna, but the results acquired are still undesirable.

As chemical sedimentary processes led to Pb isotopic homogenization and varying degree of U enrichment, some carbonate strata can be dated by using the Pb-Pb isochron dating method. Bor-ming Jahn et al. conducted Pb-Pb dating of carbonate rock, marble and dolomite (Jahn et al., 1992; Jahn and Cuvellier, 1994; Jahn and Simonson, 1995). This is one of the import approaches to solving the problem of how to date sedimentary rocks. Modern marine and lake muddy sediments are characterized by extremely homogeneous Pb isotopic composition, indicating that argillaceous rocks can reach isotopic homogenization in the process of sedimentation, and differences in Pb isotopic composition for old argillaceous rocks should be wholly ascribed to the accumulation of radiogenic lead due to the differences in U/Pb ratio for the rocks (Zhu Bingquan, 1998). So shales (especially black shales and carbonaceous slates) are the best objects for Pb-Pb isochron dating and the Pb-Pb isochron dating is an important approach to determining the ages of sedimentary rocks. Organic-rich black shales, especially those rocks that contain aromatic-series organic matter are strongly capable of adsorbing U, and, therefore, the μvalues are very high. It is believed that the aromatic-series organic matter is an excellent object for Pb-Pb isochron dating. Better results have been achieved from the Pb-Pb isochron dating of the Kunyang Group strata in central Yunnan (Chang Xiangyang and Zhu Bingquan, 2002).

The Chengjiang Fauna (Zhang Wentang, 1987) refers to the coexisting bio-fossils consisting of duricrust arthropods and abundant Metazoae occurring in the yellowish-green shales at the upper part of the Yu'anshan Member of the Early Cambrian Qiongzhusi Formation (some of these paleospecies still maintain the signs of imprints of soft diosoma tissues) (Jiang Zhiwen, 2000) in Chengjiang and its vicinities. The Chengjiang Fauna occurs stratigraphically in the middle and lower parts of the Yuanshan member yellowish-green shales of the Qiongzhusi Formation of the Lower Cambrian series, underlying the Qiongzhusi Formation are black carbonaceous shales. Such "black color" should be caused by organic carbon accumulated after the death of algae in seawater. In the process of diagenesis, under the action of large quantities of bacteria, algae and organic acids, the clastic clay minerals were converted to other kinds of clay minerals. Such

conversion would affect the crystal structural layer, thus leading to ion exchange and further giving rise to isotope compositional homogenization. As a result, the black shales are the ideal objects for isotopic dating. After their formation, the black shales did not suffer later tectonic events, so their rock-forming ages can be acquired through isotopic dating.

2 Analytical method

Lead isotopic analysis was conducted at the Lab. of Isotope Geochemistry, Guangzhou Institute of Geochemistry, Chinese Academy of Sciences. The sample was precisely weighed and put into a Teflon tank followed by the addition of suitable amounts of HF and HNO_3. Then the solution was ultrasonically vibrated and heated to dissolve the sample. Cation resin was used to separate Pb. The Pb background in the whole experimental procedure was 2×10^{-10} g. The Pb isotopic ratios were measured on a VG-354 mass spectrometer and the instrumental state was monitored with an international standard sample (Chang Xiangyang et al., 1998). During sample analysis the standard sample NBS-981 yielded the average values of $^{206}Pb/^{204}Pb=16.934 \pm 0.007$, $^{207}Pb/^{204}Pb=15.486 \pm 0.012$ and $^{208}Pb/^{204}Pb=36.673 \pm 0.033$. The precision of Pb isotopic analysis is better than 0.07%.

3 Results and discussion

3.1 Results

Results of the Pb isotopic analysis for carbonaceous shale samples collected from the Meishucun section and yellow shale samples collected from Maotianshan, Chengjiang, are listed in Table 1 and the isochron ages were calculated with the software *ISOPLOT* (Ludwig, 1991).

Relatively significant variations were noticed in Pb isotopic composition for the black shale samples (Table 1): $^{206}Pb/^{204}Pb$: 20.53–26.53; $^{207}Pb/^{204}Pb$: 15.78–16.11, and $^{208}Pb/^{204}Pb$: 38.85–42.99. Twenty data points constitute a Pb-Pb isochron (Fig. 1), yielding an age of 534±60 Ma (only a part of all errors was taken, i.e., data distribution and analytical errors, all the errors are about 190 Ma), and MSWD is 6.81. In addition the data points representing 6 black shale samples fall beyond the isochron. Samples Ky97-4 and Ky97-7 are relatively coarse in grain size, sample Ky97-10 was coarse in grain size, intercalated with light-colored bands, and samples Ky-97-9, Ky97-13-3 and Ky97-14 are massive in shape and relatively light in color.

The Pb isotope data of the Maotianshan yellow shale samples are less variable, i.e., $^{206}Pb/^{204}Pb$: 20.36–23.82; and $^{207}Pb/^{204}Pb$: 15.79–16.03. The data points representing 12 samples constitute an isochron of reference significance (Fig. 2), indicating that weathering has destroyed the Pb isotopic systematics.

3.2 Discussion

As the Chengjiang Fauna occurs in a suite of strongly weathered yellowish-green shales and there is no highly sophisticated technique available for isotope dating of sedimentary rocks, no reliable isotopic age has yet been acquired, even up to now, for the Chengjiang Fauna.

In the year of 1984 Luo Huilin et al. carried out isotope dating of the Shiyantou Member of the Qiongzhusi Formation of the Meishucun section at Jinning and acquired a whole-rock Rb-Sr isochron age of 579.7±8.2 Ma (Luo Huilin et al., 1984). In their further studies an age of 570.7±4.7 Ma was obtained for black shales in the lower part (Luo Huilin et al., 1994). Xing Yusheng and Luo Huilin, (1984) adopted the same isotope dating method to determine the age of black shales of the Shiyantou Member (587±17 Ma). In order to determine the boundary age between the Precambiran and the Cambrian, Luo Huilin et al. collected phosphorite samples from the upper part of the Zhongyicun Member. Rb-Sr isotopic analysis was

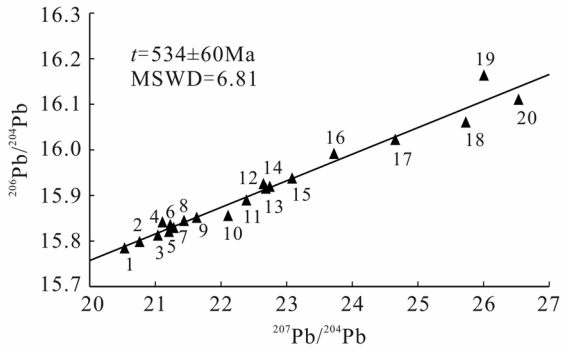

Fig. 1. Pb-Pb isochron of black shales from the Meishucun section, Jinning, central Yunnan Province (Point Nos. are the same as in Table 1).

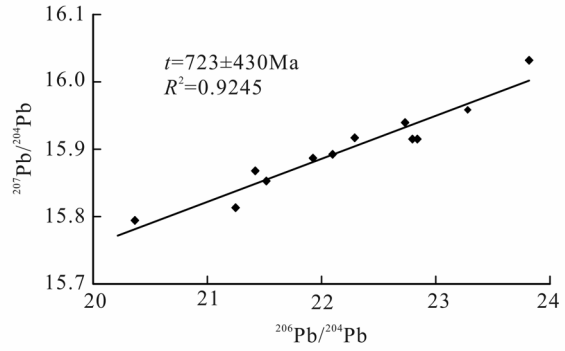

Fig. 2. Pb-Pb isochron of yellow shales from Chengjiang, central Yunnan Province.

Table 1. Pb isotope data of the Cambrian black shales from Jinning and yellow shales from Chengjiang, central Yunnan Province

Sample No.	Rock type	No.	$^{206}Pb/^{204}Pb$	2σ%	$^{207}Pb/^{204}Pb$	2σ%	$^{208}Pb/^{204}Pb$	2σ%
Cj97-1	Yellow shale		23.283	.012	15.958	.016	38.593	.010
Cj97-2			22.792	.011	15.915	.012	38.600	.013
Cj97-4			23.819	.019	16.032	.029	44.597	.030
Cj97-6			22.838	.012	15.915	.019	43.733	.015
Cj97-8			22.287	.016	15.917	.018	43.044	.018
Cj97-10			22.734	.009	15.940	.011	43.514	.010
Cj97-12			21.252	.046	15.813	.041	40.660	.049
Cj97-14			21.511	.014	15.852	.018	41.612	.016
Cj97-16			20.361	.010	15.794	.011	40.617	.011
Cj97-18			22.095	.007	15.892	.009	42.399	.010
Cj97-20			21.417	.009	15.867	.009	41.594	.010
Cj97-22			21.927	.012	15.887	.013	42.748	.013
Ky97-1	Carbonaceous shale	11	22.388	.018	15.889	.020	39.770	.019
Ky97-2		14	22.744	.010	15.919	.008	40.019	.008
Ky97-3		9	21.631	.014	15.851	.014	40.575	.015
Ky97-4			23.228	.019	15.805	.019	39.087	.022
Ky97-5		7	21.280	.013	15.829	.013	39.736	.013
Ky97-6		3	21.040	.011	15.812	.014	40.264	.014
Ky97-7			21.261	.049	15.784	.044	40.139	.048
Ky97-8		6	21.227	.020	15.835	.026	40.385	.026
Ky97-9			20.668	.033	15.739	.031	39.817	.034
Ky97-10			20.858	.042	15.735	.044	40.012	.046
Ky97-11		19	26.005	.024	16.163	.027	39.158	.026
Ky97-12		5	21.208	.042	15.820	.044	39.061	.048
Cb-I-1		20	26.534	.011	16.110	.011	39.829	.012
Cb-I-2		15	23.084	.015	15.937	.019	43.296	.016
Cb-I-3			22.463	.021	15.990	.032	43.410	.028
Cb-I-4		13	22.681	.011	15.915	.012	42.998	.011
Cb-I-5		12	22.647	.040	15.925	.062	42.901	.057
Cdpd-I-1		4	21.107	.014	15.841	.018	40.707	.025
Cdp-I-2		2	20.759	.024	15.798	.026	40.353	.028
Cdp-I-2-j		1	20.530	.009	15.784	.013	40.213	.015
Cj-I-1		16	23.721	.032	15.991	.041	40.908	.041
Ky97-11-1		17	24.656	.032	16.022	.052	38.858	.027
Ky97-11-2		18	25.729	.017	16.060	.017	39.624	.014
Ky97-13-1		10	22.107	.006	15.855	.006	39.339	.006
Ky97-13-2		8	21.436	.015	15.844	.017	39.436	.019
Ky97-13-3			20.732	.032	15.796	.058	39.55	.044
Ky97-14			22.668	.049	15.863	.058	39.915	.035

conducted on whole-rock and acid-insoluble substances after the samples were treated with acid. The acquired isochron age is 596.9±4.6 Ma (Luo Huilin et al., 1991). As determined by Luo Huilin et al. (1984), the Rb-Sr isochron age is 556.8±10.7 Ma for the black shales of the Yu'anshan Member. Yang Jiedong et al. (1996) employed the Sm-Nd method to date the Cambrian strata in Yunnan, Sichuan and Xinjiang of China and acquired their Cambrian basal boundary ages of 560–570 Ma. In regard to sedimentary rocks such as sandstones and shales, it is hard to determine whether the Rb-Sr isotopic systematics could maintain its closure. So whether these Rb-Sr isochron ages can represent the age of sedimentary rocks is still an open question. Recently, Chen Liangzhong et al. (2001) dated illite separated from black shales of the Yu'anshan Member of the Heilinpu Formation of the Dapotou section at Chengjiang and acquired a $^{40}Ar/^{39}Ar$ plateau age of 559.63 ± 0.98 Ma; the $^{40}Ar/^{39}Ar$ plateau age of illite separated from black shales of the Yu'anshan Member of the Heilinpu Formation of the Meishucun section at Jinning is 559.22±0.77 Ma. The Yu'anshan Member is the stratigraphic position where the Chengjiang Fauna occurs, which is far away by two fossil zones from the Precambrian/Cambrian boundary in the upper part of the Zhongyicun Member, i.e., the *Paragloborilus-Siphogonuchites* zone and the *Sinosachites-lapworthella* zone (Luo Huilin et al., 1982, 1994). So, the above-mentioned results of age determination seem more reasonable.The Cambrian basal boundary age was 543.9±0.24 Ma as determined by the U-Pb method, which is used internationally, on zircon from volcanic ashes (Bowring et al., 1993) and this age is slightly older than what is presented in "International Stratigraphical Time Scale" and "Whole Regional Chronological Strata (Geological Time) Scale". In combination with the results obtained by previous authors, we believe that the isotopic ages of the strata where the Chengjiang Fauna occurs should be within the range of 540–530 Ma.

4 Conclusions

As there are some difficulties in methodology for the dating of sedimentary rocks, it is hard to determine the accurate age of the Chengjiang Fauna which occurs in the shales, thus exerting a great impact on the deep-going study of the Chengjiang Fauna. Although the yellow shale samples in which are contained fossils of the Chengjiang Fauna did not yield their Pb-Pb isochron ages, the underlying black shales which have not been affected by weathering yielded Pb-Pb isochron ages, which should represent the lower-limit ages of fossils of the Chengjiang Fauna. As viewed from the results of previous studies, we considered that the strata where fossils of the Chengjiang Fauna occur should be as old as 540–530 Ma. To use new dating methods to determine the ages of fossils of the Chengjiang Fauna on a trial basis is helpful to perfect the dating method for sedimentary rocks, and also is of great significance in deep-going research on the Chengjiang Fauna.

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