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RESEARCH ARTICLE

Sedimentary geochemistry of chert from the Middle–Upper Ordovician in Shihuigou area, North Qilian orogenic belt and its tectonic implication

DU Yuansheng (✉), ZHU Jie, GU Songzhu

Faculty of Earth Sciences, China University of Geosciences, Wuhan 430074, China

Abstract The North Qilian orogenic belt is an elongate tectonic unit that lies between the North China plate to the north and the Middle Qilian microplate to the south, and is formed by a collision of the two plates in the Caledonian. The Shihuigou Section from Yongdeng County, Gansu Province, is in the eastern sector of the North Qilian Mountains, spanning the Ordovician island-arc zones. The Zhongpu Group is distributed in the Shihuigou area and composed of medium-basic volcanic rocks and volcanic clastic rocks interspersed with cherts, limestones, slates, and metamorphic sandstones. The geochemistry of chert from the Zhongpu Group reveals that all cherts coexisting with island-arc volcanic rocks formed in a continental margin basin environment. Research results of the rare earth elements reveal that these cherts formed in a relatively deep-water basin with no significant terrestrial interference. Therefore, it is inferred that the North Qilian orogenic belt was previously an archipelagic ocean in the Ordovician.

Keywords North Qilian orogenic belt, Ordovician, chert, sedimentary geochemistry, tectonics

1 Introduction

The North Qilian orogenic belt is an elongate tectonic unit that lies between the North China plate to the north and the Middle Qilian microplate to the south. As a subunit of the Qilian orogenic belt, the North Qilian orogenic belt is defined by a number of tectonic lineaments (Fig. 1). The northern margin of the belt is divided from the North China plate by the Longshoushan fault, the eastern by the Tongxin–Guyuan fault, the western from the Tarim plate by the Altyn fault, and the southern margin of the belt is bounded by the northern boundary fault of the Middle Qilian. The North Qilian orogenic belt consists of units featuring various geological settings, including back-arc basin, island-arc, subductive complex, and oceanic crust remnant slice (Xiao et al., 1978; Wu and Song, 1992; Xu et al., 1994; Feng and He, 1996; Xia et al., 1996; Zhang et al., 1997). The North Qilian orogenic belt has experienced the following tectonic evolution history: continental rift (Sinian–Cambrian), oceanic basin (Early Ordovician), active continental margin (Middle–Late Ordovician), and collision orogeny (Silurian) in the Caledonian (Feng and He, 1996; Zhou et al., 1996; Zhang et al., 1997; Du et al., 2003, 2004). This article presents sedimentary geochemistry data of the chert from the Middle–Upper Ordovician of Shihuigou area, North Qilian orogenic belt, and interprets the tectonic setting of the North Qilian orogenic belt.

2 Geological setting

The Shihuigou Section of Yongdeng County is in the eastern sector of the North Qilian orogenic belt and is situated in the North Qilian island-arc zone. Lithologically, this section consists of volcanic rocks, volcanic clastic rocks, and normally sedimentary rocks of the Middle–Upper Ordovician (Zhang et al., 1995; Zhou et al., 1996; Bureau of Geology and Mineral Resources of Gansu Province, 1997). The volcanic rocks are dominated by medium-basic volcanic rocks, including basalt, basaltic andesite, andesite, spilitic porphyrite, brecciated lava, spilitic volcanic clastic rock, alkali-trchybasalt and trachite, belonging to island-arc tholeite, calc-alkali basalt, and peridotite trchybasalt series. According to petrochemical features, the volcanism occupies sequential characters of effusion, eruption-strong, eruption-intermittent, and eruption-peaceful periods (Feng, 1992; Xia et al., 2003;

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E-mail: dxyyz@cug.edu.cn

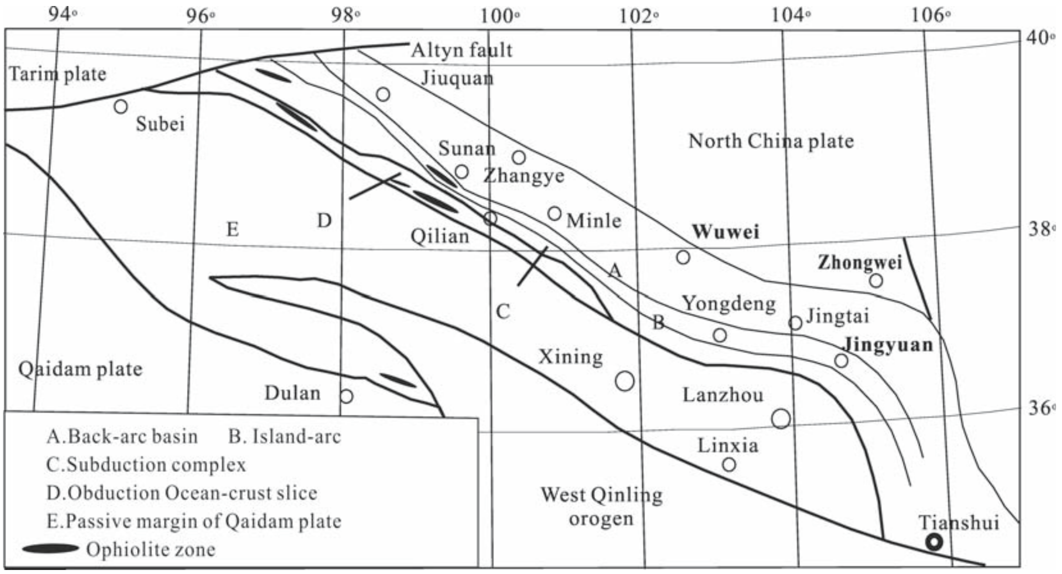

Fig. 1 Tectonic framework of the North Qilian orogenic belt (modified from Feng and He (1996))

Xu et al., 2003). The sedimentary rocks include cherts, sandstones, slates, and massive limestones, interbedded with the volcanic rocks, forming a stratigraphic series of lava-volcanic clastic rock-sedimentary rocks interbedded with volcanic rock-sedimentary rocks. Graptolites such as *Nemagraptus gracilis*, *Hallograptus* sp., *Climacograptus* cf. *latus*, *C. forticaudatus, Glyptograptus teretiusculus, G. englyphus, Glossograptus* sp., *Pseudoclimacograptus* sp., *Amplexograptus* sp., *Orthograptus* sp., *Cryptograptus* cf. *tricornis, Dicragraptus* sp., and *Isograptus* sp. are found in slates of the Zhongpu Group. Conodonts such as *Balodina* sp., *Acodus* sp., *Scolopodus varicostatus*, and trilobites, including *Ampyx* sp., *Atractopyge* sp., *Illaenus* cf. *sinensis*, are found in the limestones of the Zhongpu Group, which represents the Early Ordovician (Late Ningguo Period) to Middle Ordovician (Hule Period) (Bureau of Geology and Mineral Resources of Gansu Province, 1997). The Sm-Nd isotopic age of the basalt is (465.68 ± 23.18) Ma, the Rb-Sr isotopic age of the basalt is (444.9 ± 0.7) Ma, and the Rb-Sr isochronic age of peridotite dolerite is (457 ± 8) Ma, corresponding to Middle–Late Ordovician (Xia et al., 1996).

Without the exposure of the base, the Ordovician strata in the Shihuigou area are incomplete. They are unconformably overlain by the Upper Silurian. The Ordovician is divided into two structural slices according to the intensity of structural deformation (Fig. 2). Three layers of chert were found in the Shuinichang slice that lies in the south of the Shihuigou area. A single layer of chert is 100–150 m thick, and consists of dark massive cherts, purple and gray greenish mid-thin-bedded cherts and gray mid-thin-bedded or laminar cherts. Among the volcanic rocks, lava is more abundant than pyroclastics. Pillow basalt in the mid-lower parts of the Shuinichang slice is more than 100 m thick. In the north of Majiazhuang slice, more cherts are exposed, with a thickness less than 50 m, which includes dark-gray massive cherts and thin-bedded cherts, cherts interbedded with sandstone and slate northward. The volcanic rocks mainly consist of lava with air cavity-almond structure and mid-basic pyroclastics. According to the evolution of volcanic rocks and the fossil data, the age of the Majiazhuang slice is thought to be later than that of the Shuinichang slice.

3 Petrology and method

Ten chert samples were collected from the Shihuigou area, among which 7 are dark-gray chert from the Majiazhuang slice. The thin-bedded samples (SH6-5, SH6-7, SH6-8) and thick massive or bedded samples (Y301, Y302, Y303, Y305) are all microcrystal-aphanitic in texture, and mainly composed of microgranular and aphanitic silica (grain size 0.01–0.1 mm). Siliceous content is greater than 82%, including oriented sericite, clay and iron mineral, with different ankerite and limonite. The other three chert samples (SH24-1, SH24-3, SH28-1) are from the Shuinichang slice and are dark-gray mid-thin bedded cherts, with a microcrystal-aphanitic texture and micrograded bedding. The content of microcrystal quartz and aphanitic silica is about 82%–95%. The chert contains a few sericite, clay, and iron mineral. No quartz vein is present in the samples. The samples were crushed into small pieces and then fresh pieces without quartz veins were chosen for analysis.

All samples were crushed at the Hubei Institute of Geological Experiment. Each sample was analyzed by both X-fluorescence spectrum for major elements, in the Hubei Institute of Geological Experiment, and ICP-MS for rare earth elements in the State Key Laboratory of Geological Processes and Mineral Resources of China University of Geosciences.

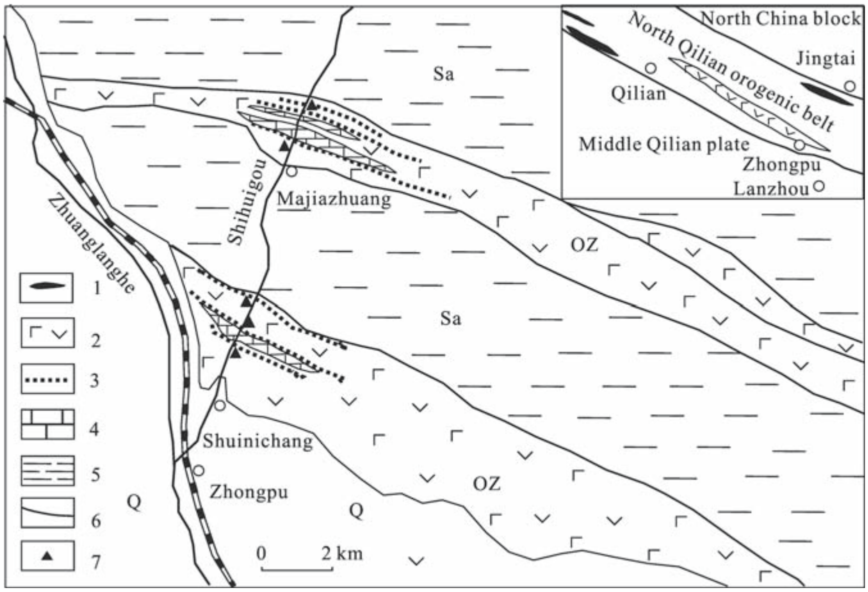

Fig. 2 Simplified geological map of the Shihuigou area, North Qilian Mountains and sample location (modified from Bureau of Geology and Mineral Resources of Gansu Province (1997)). Q. Quaternary; 1. ophiolite; 2. island-arc volcanic rock of Zhongpu Group; 3. chert; 4. limestone; 5. sandstone and slate of Angzanggou Formation; 6. fault; 7. location of chert sample

4 Geochemistry and depositional environment of the chert

4.1 Major elements

Major elements Fe, Mn, and Al are important indicators in distinguishing biogenic and hydrothermal cherts. Fe and Mn are usually concentrated in a pelagic basin, while the enrichment of Al indicates refluence of terrigenous material. Bostrom et al. (1969) pointed out that the Al/(Al + Fe + Mn) ratio would be a valuable marker to evaluate the hydrothermal significance of the marine sediments. Adachi et al. (1986) and Yamamoto (1987) noticed that these ratios vary from 0.01 (pure hydrothermal origin) to 0.60 (pure biogenic origin). Table 1 shows that the Al/(Al + Fe + Mn) ratios range from 0.53 to 0.76, indicating that the cherts are of biogenic origin.

According to the study of modern oceanic sediments, Bostrom et al. (1973) established an Fe/Ti-Al/(Al + Fe + Mn) diagram and divided modern oceanic sediments into three types of origin: biogenic, terrigenous, and hydrothermal ones. According to the ratios of Al/(Al + Fe + Mn) and the Fe/Ti-Al/(Al + Fe + Mn) diagram, all the samples are plotted in or near the continental margin sediment area (Fig. 3a). In the Al-Fe-Mn triangular diagram proposed by Bostrom et al. (1969) and Yamamoto (1987), hydrothermal chert would be plotted in area B and biogenic chert in area A. All the 10 samples are plotted in area A (Fig. 3b), supporting a biogenic origin without hydrothermal effect.

Murray (1994) considered that Al and Ti are closely related to terrigenous Si and suggested it as an important indicator of terrigenous origin. Fe is enriched from the sediments near an ocean ridge area and can be used as an indicator of a hydrothermal source from a sea floor spreading center. Murray (1994) proposed a tectonic setting diagram of the geochemical components of cherts, in which three plotting areas were defined as continental margin, ocean basin, and ocean ridge areas. Fig. 3c shows that all the samples in Shihuigou are in or near the range of the continental margin area. In Fig. 3d, most of the samples are in or near the range

Table 1 Content of major elements (%) of Ordovician chert from Shihuigou

Samples	SiO_2	Al_2O_3	Fe_2O_3	FeO	CaO	MgO	K_2O	Na_2O	TiO_2	P_2O_5	MnO	H_2O^+	CO_2	∑	Al**	MnO/TiO_2
SH6-5	87.97	3.90	1.09	1.30	0.62	1.09	1.16	0.02	0.19	0.04	0.12	1.71	0.64	99.85	0.70	0.63
SH6-7	82.98	5.76	1.65	1.73	1.38	1.07	1.51	0.04	0.32	0.05	0.16	2.36	0.76	99.77	0.71	0.50
SH6-8	97.23	0.77	0.27	0.23	0.25	0.20	0.25	0.02	0.05	0.04	0.01	0.50	0.20	100.02	0.69	0.20
Y301	91.40	2.61	2.78	0.33	0.32	0.12	0.41	0.12	0.15	0.13	0.04	1.24	0.2	99.85	0.56	0.27
Y302	95.48	1.15	0.71	0.27	0.16	0.12	0.49	0.08	0.11	0.03	0.02	0.61	0.08	99.87	0.70	0.18
Y303	89.94	1.71	1.30	0.33	1.13	0.19	0.82	0.12	0.21	0.08	0.17	1.17	0.65	99.85	0.76	0.81
Y305	82.62	3.74	2.05	1.57	4.68	0.66	0.41	0.10	0.16	0.05	0.16	1.42	3.08	99.85	0.53	1.00
SH24-1	87.52	2.89	1.91	0.50	0.39	0.35	1.08	0.04	0.24	0.06	0.01	1.76	0.72	99.50	0.76	0.04
SH24-3	94.94	4.92	0.41	0.37	0.24	0.25	0.36	0.04	0.10	0.04	0.01	0.86	0.26	99.22	0.72	0.10
SH28-1	95.92	4.99	0.08	0.42	0.60	0.18	0.28	0.07	0.10	0.05	0.01	0.54	0.42	99.82	0.76	0.10

* The samples are analyzed by X-fluorescence spectrum for major elements in the Hubei Institute of Geological Experiment. Al**. Al/(Al + Fe + Mn)

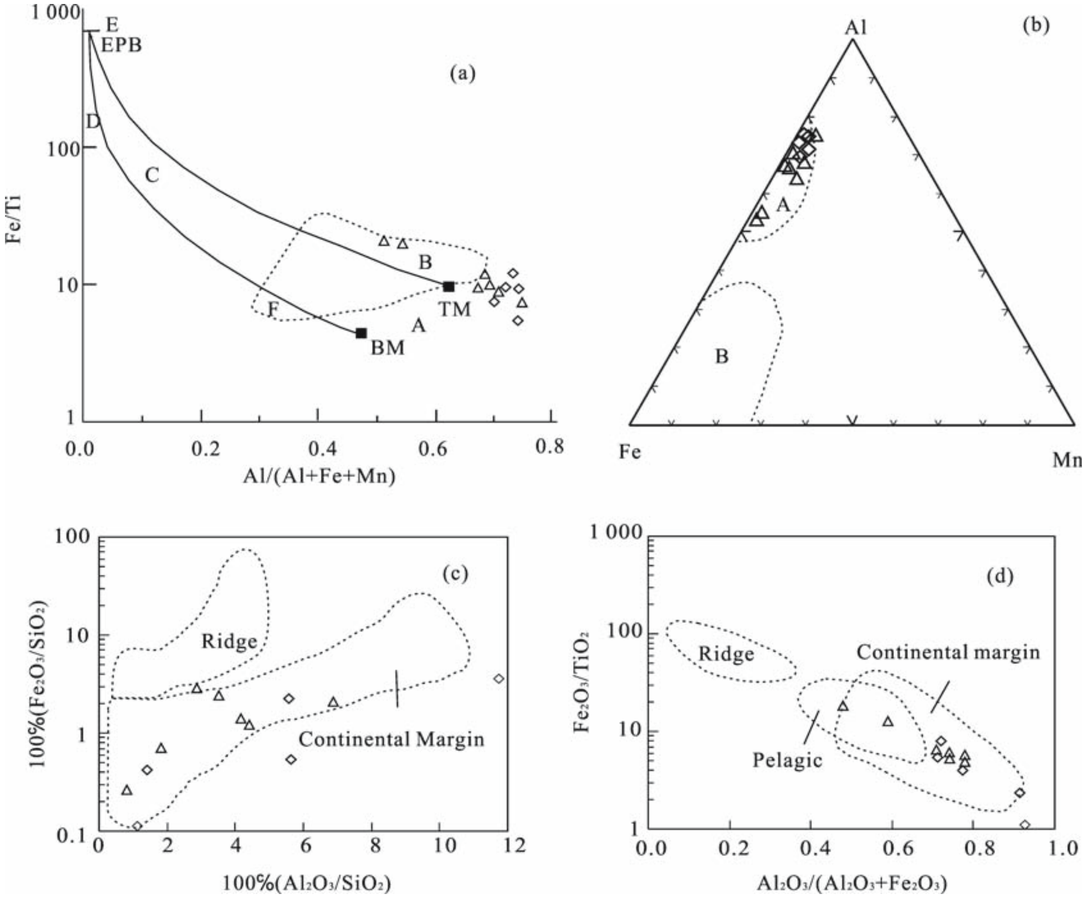

Fig. 3 Major element discrimination diagrams of Ordovician cherts from Shihuigou
(a) Fe/Ti-Al/(Al + Fe + Mn) diagram of modern oceanic sediments (from Bostrom et al., 1973). A. Biogenic chert; B. average ocean clay; C. hydrothermal sediment; D, E. hydrothermal clay; F. West Pacific Ocean sediment; EPR. hydrothermal partial sediment; TM. continental margin sediment; BM. biogenic sediment; (b) triangle diagram of Al-Fe-Mg from chert samples (from Adachi et al., 1986): A. biogenic chert area, B. hydrothermal chert area; (c) 100 × (Fe_2O_3/SiO_2)-100 × (Al_2O_3/SiO_2) diagram (from Murray, 1994); (d) Fe_2O_3/TiO_2-$Al_2O_3/(Al_2O_3 + SiO_2)$ diagram. Δ chert samples from Majiazhuang; ◊ chert samples from Shuinichang

of the continental margin area, except for 2 samples from Majiazhuang, which overlap the ranges between continental margin and oceanic basin.

The ratio of MnO/TiO_2 can be used to estimate the origin of sedimentary material and the paleogeographical locality of the sedimentary basins. The cherts from continental margin basins have a lower MnO/TiO_2 ratio, generally less than 0.5; whereas the pelagic cherts have higher ratios: 0.5–3.5 (Murray, 1994). The MnO/TiO_2 ratios of all samples from Shihuigou shown in Table 1 are less than 1, averaging 0.42. The MnO/TiO_2 ratios of 7 samples from the Majiazhuang slice vary from 0.18 to 1.00, 2 samples are over 0.80, and the average is 0.51. The ratios of 3 samples from the Shuinichang slice vary from 0.04 to 0.10. This indicates that the cherts were of typically continental margin origin. Compared to cherts from the lower part of the Shuinichang slice, cherts from the Majiazhuang slice formed in a more open continental margin environment. This implies that oceanic basin spreading existed in the Middle–Late Ordovician.

4.2 Rare earth elements

It is clear that the total REE (ΣREE) content of chert is higher in an environment influenced by terrigenous material, such as a continental margin basin or relict basin. But in pelagic and deep-sea basins that are far away from a terrigenous material environment, chert could absorb more REE from sea water (Murray et al., 1990, 1992, 1994). The La_n/Ce_n ratio of chert also correlates with its sedimentary environment. The La_n/Ce_n ratio of chert formed in a continental margin varies from 0.5 to 1.5, chert formed in an oceanic basin varies from 1.0 to 2.5, and chert deposited in an oceanic ridge basin is about 3.5 (Murray et al., 1990, 1992, 1994). The Ce anomaly of cherts appears to coincide with the character of sea water, terrigenous supply and sedimentary speed (Murray et al., 1990, 1992, 1994). The study of modern sedimentary environments indicates that there is no fractionation present between Ce and other REE in river water. Elderfield et al. (1990) reported that the δ (Ce) in 40 rivers varies from 0.7 to 1.2, averaging 1.0. The Ce anomaly of water from a gulf is similar to that from a river. The δ (Ce) of sea water from a coast is also similar to that from a gulf and is about 0.8–1.2. No evident Ce anomaly is shown in the NASC-normalized REE abundance pattern. The δ (Ce) of sea water in an open oceanic basin is extremely low, varying from 0.2 to 0.3. The δ (Ce) could change with sea-water depth, and δ (Ce) in anoxic seawater is much higher than in oxygenated seawater, implying that the Ce content is related to an oxidation-reduction environment (Ormiston and Lane, 1976). The Ce negative anomaly of sediments could be correlated with Ce of sedimentary media. Continental margin water shows inconspicuous Ce depletion. Murray (1994) indicated that δ (Ce) averages of chert formed in a continental margin vary from 0.67 to 1.35. Limited sea basins or oceanic basins (e.g., the Mediterranean Sea, the Red Sea) influenced by terrigenous material exhibit no obvious negative Ce anomalies. The sea water of the typical open oceanic basin shows extreme Ce depletion, and deep-sea sediments exhibit obvious negative Ce anomalies about 0.25. For example, the sea at a depth of 2 000–3 000 m near the East Pacific Ocean Rise, δ (Ce) is 0.04. Therefore, obvious Ce negative anomalies could be inferred to represent a pelagic environment.

ΣREE of the cherts from Shihuigou area greatly vary from each other. The ΣREE of sample SH24-1 from the Shuinichang slice, and SH6-5 and SH6-7 from the Majiazhuang slice are over 100, with the highest value of 171.3 (SH6-5). Others vary from 30.79 to 83.9 and the highest value is 50. This indicates that the cherts formed in an active continental margin environment, and the influence of terrigenous material varied with time. The NASC-normalized abundance patterns of the cherts (Fig. 4) show that partial curves slightly tend to the right, others are flat or slightly left tending. This pattern is different from either the LREE enrichment patterns of cherts formed in a continental margin, or the HREE enrichment from cherts in an open oceanic basin. The La_n/Ce_n ratio from Ordovician chert varies from 0.49 to 0.78. The highest value is 0.60 (Table 2) and is within the range (0.5–1.5) of a continental margin. The δ (Ce) of all Ordovician cherts in Shihuigou varies from 0.77 to 0.92 (Table 2). There is no obvious negative Ce anomaly shown, which is similar to the features of the Ce anomaly of chert in a continental margin. Xu (2003) reported that the δ (Ce) of Early Ordovician cherts in Laohushan, Jingtai, varies from 0.57 to 0.77, averaging 0.14, and the La_n/Ce_n ratio is from 0.22 to 0.61, averaging 0.41. The feature of cherts from Laohushan is also similar to that of the tectonic background of a continental margin.

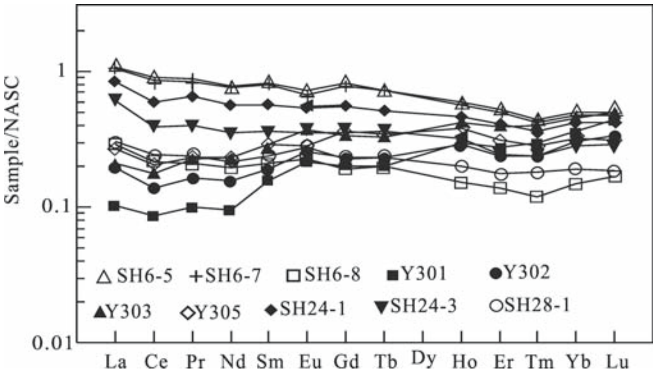

Fig. 4 NASC shale-normalized REE pattern of Ordovician cherts in Shihuigou

5 Conclusions

The North Qilian was a Caledonian orogenic belt, and might have started to break up as a rift from the Rodinia supercontinent during the latest Proterozoic, becoming a rift basin during the Cambrian, an initial ocean basin to a mature ocean basin, including trench-arc-basin system during the Ordovician, and a collisional orogenic belt during the Silurian to Early and Middle Devonian (Xiao et al., 1978; Zuo and Liu., 1987; Feng and He, 1995, 1996; Zhou et al., 1996; Du et al., 2003, 2004).

The association of volcanic rocks and ophiolites from the Ordovician implies that there was an ocean basin in North Qilian during the Ordovician (Xia et al., 1996, 1998, 2003; Zhang et al., 1997). The Lower Ordovician Yingou Group and Middle–Lower Ordovician Zhongpu Group are exposed widely in the North Qilian Mountains. The Yingou Group and Zhongpu Group consist of basalts, andesitic basalts, andesites, and volcanic clastic rocks interbedded with various

Table 2 Content of rare earth elements of Ordovician cherts (μg/g) from Shihuigou*

Sample	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	Y	ΣREE	δ (Ce)	La_n/Ce_n
SH6-5	34.8	65.7	6.93	25.9	4.69	0.89	4.26	0.62	3.16	0.62	1.77	0.22	1.54	0.24	20.0	171.3	0.92	0.60
SH6-7	33.5	63.0	6.70	24.9	4.53	0.84	4.09	0.61	3.11	0.59	1.69	0.21	1.47	0.23	19.4	164.9	0.91	0.61
SH6-8	9.19	15.9	1.67	6.43	1.21	0.28	0.99	0.17	0.88	0.16	0.47	0.06	0.46	0.08	6.96	44.9	0.87	0.66
Y301	3.29	6.28	0.79	3.16	0.90	0.27	1.03	0.17	1.27	0.31	0.93	0.15	1.12	0.21	9.84	30.79	0.77	0.71
Y302	6.20	10.2	1.29	5.20	1.09	0.32	1.20	0.20	1.27	0.30	0.81	0.12	0.94	0.16	8.08	38.10	0.78	0.69
Y303	6.79	13.0	1.77	7.63	1.65	0.46	1.77	0.28	1.86	0.44	1.32	0.20	1.41	0.24	11.2	49.98	0.82	0.59
Y305	8.56	15.0	1.84	7.59	1.66	0.35	1.90	0.29	1.77	0.40	1.06	0.14	0.99	0.15	9.69	51.35	0.82	0.65
SH24-1	27.2	43.6	5.13	18.7	3.26	0.66	2.84	0.44	2.29	0.48	1.38	0.18	1.30	0.20	15.9	123.5	0.80	0.71
SH24-3	19.4	28.3	3.19	11.7	2.09	0.44	1.85	0.31	1.50	0.33	0.83	0.12	0.87	0.14	12.8	83.9	0.77	0.78
SH28-1	9.83	17.8	1.90	7.17	1.37	0.34	1.18	0.20	1.10	0.21	0.60	0.09	0.59	0.09	8.26	50.7	0.89	0.63

* The cherts are analyzed by ICP-MS of Crust-Mantle System in the State Key Laboratory of Geological Processes and Mineral Resources of China University of Geosciences. The rare earth elements are normalized by NASC (Haskin et al., 1968).

sandstone, slate, chert, and limestone. The volcanic rocks are dominated by extravasation facies, locally by eruptive facies, and consist of massive and pillow lava. The volcanic rock belt is 800 km long, and its width varies from 1 000 to 5 000 m, extending in an E-W direction in the North Qilian Mountains. The ophiolites in Yushigou, Bianmagou, and Dachadaban and deep-level subduction complex rocks in Qingshuigou represent association of subduction complex rocks from a trench during the Ordovician. The ophiolite and shallow-level subduction complex rocks in Baiquanmen, Jiugequan, Shihuigou, and Laohushan represent the association of subduction complex rocks from an island-arc and back-arc basin. The volcanic rocks of an island-arc are distributed around the Shihuigou to Dachadaban areas, and volcanic rocks from a back-arc basin along the Jiugequan–Baiquanmen–Maomaoshan–Laohushan area (Zuo and Liu, 1987; Feng and He, 1995, 1996; Xia et al., 1996, 1998, 2003; Zhang et al., 1997; Du et al., 2003, 2004). The back-arc volcanic rocks in a typical back-arc ophiolite sequence in the Jiugequan and Laohushan areas belong to back-arc spreading submarine volcanic rocks that mainly consist of basic volcanic rocks. These volcanic rocks have quenching textures, for example, skeletal texture of plagioclase microcrystal from pillow lava, radial and parallel spinifex texture of orthopyroxenes and so on. Major, trace, and rare earth element data show characteristics of back-arc basin volcanic rocks (Xia et al., 2003). Therefore, it can be estimated that a typical active continental margin with a trench-arc-basin system developed in North Qilian during the Ordovician. An island-arc volcanic zone developed in the Shihuigou area, and a back-arc basin volcanic zone developed in the Maomaoshan and Gulangshan areas in north of Shihuigou, in which the ophiolite zone belongs to oceanic crust remnant blocks from a spreading back-arc basin.

Graptolites and radiolarias were found from Ordovician cherts and slates in the Shihuigou area. Radiolarias with long stabs, fine body, thin crust, and dense ornamentation show that they grow in a warm deep-water environment (Wu, 1986; Feng, 1992). The cherts, slates, and fine clastic rocks constitute deep-water turbidites (Zhou et al., 1996), whereas, in the Shihuigou and Xiakouyi areas, as well as the adjacent Gulangxia area, blue-green algal, crinoid, and mollusk fossils are occasionally found in massive limestones, suggesting that the eastern sector of North Qilian area was probably a shallow sea during the Middle–Late Ordovician.

The sedimentary geochemistry of Ordovician cherts from Shihuigou also supports the preceding conclusion. The geochemical features of submarine volcanic rocks coexisting with the cherts indicate an island-arc tectonic setting. Fe, Mn, and Al contents and the $Al/(Al+Fe+Mn)$ ratio of Ordovician cherts from the Shihuigou area indicate a biogenic origin and a continental margin environment. The characteristics of ΣREE, REE pattern, La_n/Ce_n, and δ (Ce) are similar to those from a continental margin, whereas the insignificant LREE enrichment and negative Ce anomaly indicate the Ordovician ocean of the eastern sector of North Qilian was neither a typical continental margin nor a wide open ocean, but an archipelagic ocean near an island-arc and far from the continent.

The conclusion above is identical with Xu et al. (2003) and Du et al. (2006). Xu et al. (2003) studied geochemical features, including the cherts formed in an ocean ridge from the Yushigou and Chuancigou areas, the cherts deposited in an island-arc and back-arc basin in the Laohushan area: all cherts formed in a continental margin environment. Du et al. (2006) studied the cherts formed in an island-arc and back-arc basin in Bianmagou, Dachadaban, Jiugequan and Baiquanmen, in the Sunan area of the western sector of North Qilian Mountains. All cherts suggested a continental margin environment. The δ (Ce) of the cherts in Yushigou and Chuancigou varied from 0.51 to 0.75, averaging 0.63, and the La_n/Yb_n varied from 0.32 to 0.51, averaging 0.37. The δ (Ce) of the cherts in the Sunan area varies from 0.59 to 1.06, averaging 0.81, and the La_n/Yb_n varies from 0.25 to 2.94, averaging 1.03. The ratios of La_n/Yb_n above show no obvious LREE enrichment and Ce negative anomaly, indicating that the cherts were associated with a back-arc basin, island-arc, trench subduction complex and ocean ophiolite zones in the western sector of the North Qilian Mountains, and also formed in a continental margin far away from a continent. Therefore, terrigenous influence is insignificant. In conclusion, the tectonic setting of the Ordovician cherts from North Qilian orogenic belt is neither a typical continental margin nor a wide open ocean, but an archipelagic ocean near an island-arc, and far away from a continent.

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