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PROVENANCE SETTING AND EVOLUTION OF THE LOWER SILURIAN IN THE NORTHERN TARIM BASIN, NW CHINA: CONSTRAINS FROM DETRITAL ZIRCON U-PB DATING AND SANDSTONE COMPOSITION

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Abstract: The Silurian system is a critical tectonic change period in the Tarim Basin. The study of the source and origin of the sediments is greatly significant in researching the tectonic evolution and the surrounding orogenic belts. Three representative samples of the Lower Silurian in different regions of the North Tarim basin were collected and the detrital zircon was analyzed by LA-ICP-MS for U-Pb dating. Results show that there are four accumulation age intervals in the Lower Silurian: 400~600Ma (Late Ordovician), 800~1200Ma (early stage of Late Proterozoic), 1800~2000 Ma (Early Mesoproterozoic) and 2400~2600Ma (late stage of Early Proterozoic). Combined with the analyses of geochemical data and sandstone components, the results indicate that the source of the Lower Silurian in the Keping region mainly came from the Precambrian basement in the Kuqe area forming in the continental island arc environment and the sources of those in other regions mainly came from the Late Ordovician igneous rock in Kuluketage area forming in the recycle orogen tectonic setting. Besides, Precambrian zircon ages reveal that the Tarim plate had a similar aggregation-breakup evolutionary history with the Rodinia super-continent during the Neoproterozoic and the North Tarim region had a matching structure-thermal event that occurred with the formation-cracking event of the Columbia super-continent during the Mesoproterozoic period.

Key words: Detrital zircon, Lower Silurian, Tectonic setting, Tarim basin, U-Pb dating

1. INTRODUCTION

The geochemistry analysis of the mineral component of sediments in depositional basins has proven to be very useful for reconstructing the tectonic evolution of continental blocks (Condie et al., 2009; Griffin et al., 2004; Rino et al., 2008; Kuznetsov et al., 2010; Veevers & Saeed, 2008, 2009). U-Pb analysis of detrital zircons provides age spectrum, and trace element data as an adjunct to the U-Pb analyses can offer useful information on the composition of the magma from which the zircons crystallized. Thus, an integration of these different analytical datasets in sediments makes it possible to assess the magmatic history of continental crustal blocks from which the sediments were derived in terms of their ages, rock types and source materials (Adams et al., 2011). Detrital zircons in a sedimentary basin are derived from the weathering of rocks in the provenance and their subsequent transportation in fluvial systems. Therefore, if a large number of detrital zircons are analyzed, the age spectra can be used to assess the distribution of source rocks in the provenance, and the detrital zircons identified to have an igneous origin can be used to determine the major magmatic events in the source regions (Condie et al., 2009). In recent years, great progress in this field of study has significantly enlightened our understanding of the crustal evolution history as well as established inter-continental correlations within super-continental assemblies (Carter & Moss, 1999; Cho et al., 2010; Díez Fernández et al., 2010).

Before the 1990s, oil and gas exploration in the Tarim Basin primarily focused on layer segments of the Cambrian, Ordovician and Carboniferous, with very little study of the Silurian strata. This changed completely as a result of the well TZ11 with a daily flow of 29.4m^3 in the Silurian sandstone until the year 1995. Subsequently, a series of hydrocarbon reservoirs were found, such as the well TZ47, well TZ12, well TZ50, well TZ15, well MD 1 and well HD18C. At the same time, the widely distributed asphaltic sandstone of $2.7\times10^4 km^2$ in the Silurian was a major discovery (Fig. 1). Therefore, it is no doubt that there is a tremendous exploration potential of the Silurian strata in the Tarim basin (Liu et al., 2000; Liu et al., 2004; Guo & Chen, 2006). According to the 2nd and 3rd round of resource assessments, the reserve volume of oil and gas in the Silurian strata could reach 10 million tons, and is accumulated mostly in the Central Tarim area, Northern Tarim area and the Yingjisu depression in the Eastern Tarim region (Wang et al., 2009). Recent in depth studies have revealed that the Lower Silurian strata in the Tarim Basin mainly developed in the northern Tarim area with a continental shelf-delta depositional system (Jia et al., 2006; Zhu et al., 2002). However, there is still much uncertainty regarding the origin of the lower Silurian source material and its tectonic evolution in the northern Tarim region, especially the source direction between the western region and eastern region in the Northern Tarim area (Wu et al., 2009). In this study, zircon U-Pb dating techniques were carried out on the Lower Silurian sandstone in the northern Tarim area, combined with other geochemical data in sediments and petrologic quantitative data. We studied the source direction and material characteristics of the sandstone. Subsequently, it is possible to indicate the tectonic origin of the mother rocks for the Lower Silurian sandstone.

2. GEOLOGICAL SETTING

The Tarim Basin is a composite of several small proto-type basins formed in different periods. The basin evolution is characterized by being multi-cycle and having distinct stages (Tang et al., 2000). The Mesoproterozoic-Neoproterozoic collision occurred between the Proterozoic Tarim plate and the Kazakhstan-Yili Block in the north, followed by the formation of the Xinjiang craton (BGMRXUAR, 1993; Tian et al., 2010). In the Sinian-Early Ordovician systems, the north side of the Tarim plate (South Tianshan area) gradually evolved from the rift into a passive continental margin which turned into a compression belt again in Middle Ordovician-Silurian from east to west, causing the formation of a wide range of tectonic uplifts in the plate.

In the Silurian period, the Tarim basin developed as an intracratonic depression basin with interbedded sandstone and mudstone of neritic facies (Jia, 1997), and the depth of the Silurian strata differs greatly from east to west and from north to south. The greatest thickness of strata was located in the Northern Depression, which reached nearly 1,600m. Meanwhile, the thickness of strata in the Central Depression was always less than 900m (Fig. 1).

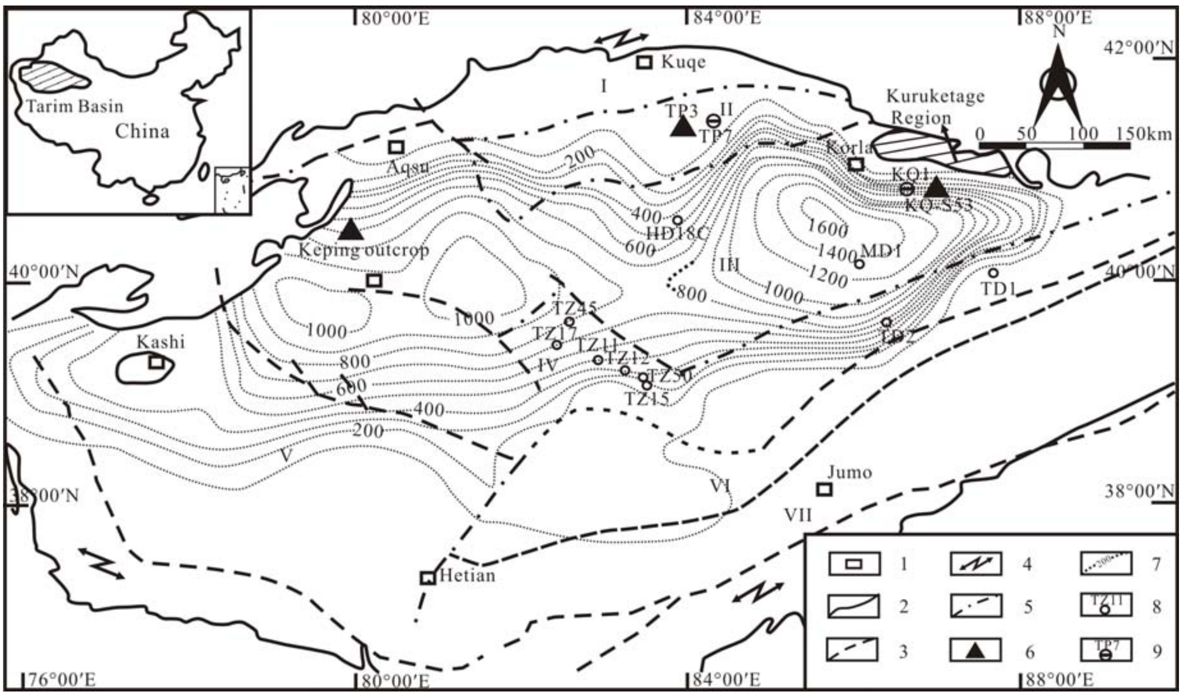

Figure 1. Distribution and sampling locations of the Silurian in the Tarim basin. I-Kuqe Depression; II- Northern Tarim Uplift; III-Northern Depression; IV-Central Depression; V-Southwestern Uplift; VI-Southern Depression; VII-Southeastern Uplift; 1-City location; 2-Basin boundary; 3-Fault; 4-Fold; 5-Structure boundary; 6-Zircon sample location; 7-Thickness isogram of the Silurian; 8-Wells discussed in this paper; 9-Location of sandstone samples used for detrital mineral testing.

The Silurian system is commonly referred to as the Kepingtage Formation, Tataaiertage Formation and Yimugantawu Formation in ascending order and the Kepingtage Formation is the formation of interest in this paper. Compared to the Ordovician and Cambrian sedimentary strata, there are more differing opinions and controversy regarding the Silurian strata because of the low degree of exploration and reservoir complexity (Cao & Chen, 1994; Guo et al., 2004). Therefore, although the depositional types of the Lower Silurian system in the Northern Tarim region have reached a consensus, the material source of the sediments and its relationship to the tectonic movement in provenance should be studied further.

3. SAMPLING AND ANALYTICAL METHODS

According to the distribution of Lower Silurian sediments in the Northern Tarim Region, three sediment samples of Kepingtage Formation were taken from different location. They included the eastern sample from well KQ-S53 which is located in the south side of the Kuluketage region, a central sample from well TP3 located in the North Tarim Uplift and the western one named KP from Keping outcrop profiles (Fig. 1). Zircons were separated from the crushed rocks using conventional heavy liquid and magnetic techniques and then handpicked under a binocular microscope in the Langfang Regional Institute of Geology and Mineral Survey. The zircon grains were mounted in an epoxy resin, then polished and coated with gold. The mounts were photographed under transmitted and reflected lights for identifying analyzed grains. The U-Pb dating of the zircon samples was also carried out using ICP-MS from PE Corporation at the State Key Laboratory of Geological Process and Mineral Resources, China University of Geosciences, Beijing. ICP-MS is equipped with four instruments of dynamic reaction cells and laser instruments for ArF 193nm. Most analyses were performed with a beam diameter of 30~50μm, 20 Hz repetition rate and energy of 200mJ per pulse. In addition, according to the determination of the isotope ratio of zircon, the detection limit of elements generally has a ppb level (Mo et al., 2006). The isotope ratios and U-Pb ages of the microzone test points in each zircon was calculated by GLITTER (ver4.0) and drawings of the concordia diagrams taken by Isoplot 3.0.

In addition, seven sedimentary rock samples named in sequence from KP1 to KP7 were collected from the Keping outcrop in the Kepingtage formation and all of which underwent trace elements and rare earth elements tests (REE). Trace elements and REE were tested also at the State Key Laboratory of Geological Process and Mineral Resources. Major elements were determined by the XRF method in the X-ray fluorescence spectrometer (3080E). All of the rare earth elements were also determined with ICP MS while the elements Sr and Ba were detected by the (IRIS) ICP-AES method.

4. RESULTS AND DISSCUSSION

4.1. Zircon U-Pb ages

4.1.1. Dating results in different samples

We obtained 80, 80 and 80 groups of age data from samples KP, TP3 and KQ-S3, all of the data have <28% discordance with the phenomenon of U-Pb losing, which indicates that most of the zircons belonged to unaltered zircons (Fig. 2 & 3). Taking into account the concentration and large interval age range of zircons, the number of the data points is sufficient for the calculation. In this paper, $^{206}Pb/^{238}U$ apparent ages are able to represent the chronology characteristics. Based on the test results, it has been found that the grains show an age range of 400 to 2600Ma, reflecting the composition complexity of the mother rock.

According to the 80 groups of age data obtained from sample KP, it is clear that all ages ranged from 520~2890Ma with peaks at 800~1200Ma, 1800~2000Ma and 2400~2600Ma, and the calculations show that the average ages were 885±12Ma, 1950±20Ma and 2458±83Ma. There are huge similarities in the apparent ages of detrital zircons between the TP3 sample and KQ-S53 sample, and both of them have an age range of 280 to 2900Ma with small peaks at 400~600Ma, 800~1000Ma and 2400~2700Ma, which is clearly smaller than the ones in the KP sample. Besides, the average apparent ages have been calculated according to Concordia diagram, which shows 437±80Ma (Fig. 2).

4.1.2. Source direction analysis

The age spectra of the detrital zircons have been successfully employed to derive information on the features of source regions in several recent studies (Condie et al., 2009; Rino et al., 2008). The dating results from Silurian sandstones in the North Tarim reveals that the mother rocks of KP sample were formed much earlier than other samples. The apparent age value of detrital zircons in the KP sample belonging to phanerozoic is under 10% (Fig. 3), which shows that most of the mother rocks were formed by the weathering on Precambrian basement rock. Meanwhile, similar dating results of TP3 samples and KQ-S53 samples reveal a compatible accumulation zone in age spectra ranging from 400~600Ma and 800~1000Ma, which shows that the mother rocks of these two samples are closely related to the igneous rocks formed in Late Ordovician and Early Silurian. Previous research has found that the denudation of Precambrian basement only happened in Kuqe area in the Northern Tarim region (Jia, 1997), which proves that the main source of the Lower Silurian in the Keping area should extend from the Kuqe region. In addition, the Kuruktag region (Fig. 1) turned into a compression tectonic environment in Late Ordovician accompanied by a greater amount of volcanism (Li et al., 1992). Thus, the Kuruktag region is the most likely provenance for the TP3 sample and KQ-S53 sample.

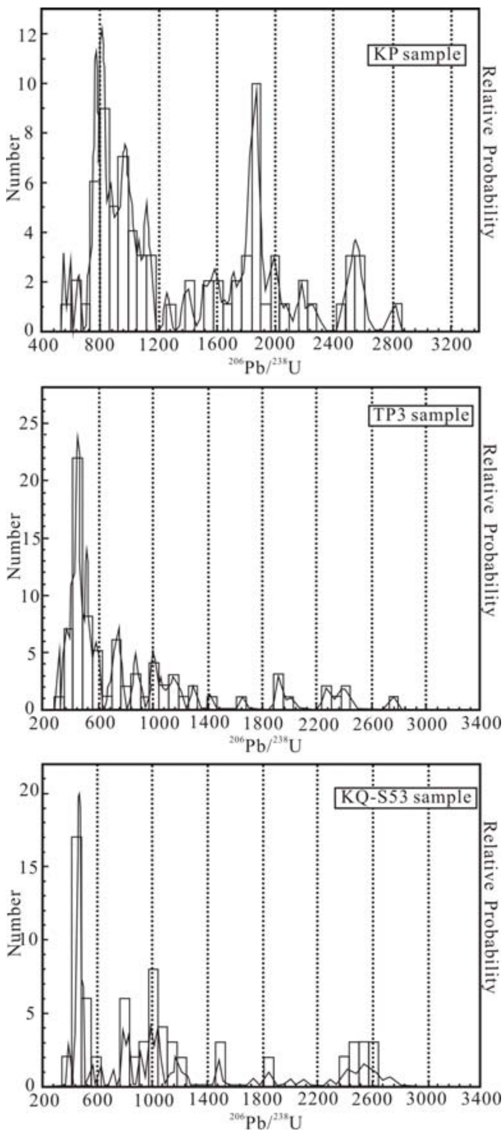

Figure 2. Frequency spectrum of clastic zircon $^{206}Pb^{238}U$ ages of the Northern Tarim region

The ZTR maturity index can also be taken as another evidence to prove the differential in source direction between the Keping region and other regions (Fig. 4), the values of which are always above 35% in the Keping region while the values are often below 30% (even <20%) in wells TP3 and TP7 which are located in central Northern Tarim region. The low maturity degree of the sandstone in the wells TP3 and TP7 represents a near-source environment and the relatively high maturity degree in the Keping region indicates its distal feature, which is consistent with the above conclusion about the source direction.

4.1.3. Age date and tectonic events

In the Neoproterozoic system, the super-ancient land (Rodinia), which contained Tarim, Junggar, Yangtze and other small land masses began to split quickly (Li et al., 1992; Zhang, 1994; He et al., 1995, Guo et al., 2002). Some points in time found in different blocks are in accordance with this splitting event, such as the development of igneous with 760Ma in the Nanhua System in the Kuruketage region (Guo et al., 2001; Lu et al., 2004), the occurrence of cleavage with 800~750Ma in the North Qaidam basin (Yang et al., 2003) and the development of the mantle plume with 760Ma and 880Ma in the South China plate and Australia plate (Li et al., 2003). The age data of zircon from the North Tarim region also have the accumulation age interval range of 800~1200Ma, indicating that the Tarim block was a part of the Rodinia super-ancient land and split out at the same time with other blocks. In addition, the age data of zircon from the TP3 and KQ-S53 samples have a concordia age of 437±80Ma, which is in accordance with the Caledonian event in Late Ordovician. Some previous scholars realized that the Middle-Late Ordovician collision process in the Tianshan Ocean (located in the north of the Tarim block) spread from east to west. Therefore, the concordia age data may be related to the upthrust in the Kurugetage region.

In recent years, the Columbia super-continent began to be the hot topic of discussion (Rogers & Santosh, 2002; Powell & Pisarevsky, 2002). In the North Tarim area, there was also some old data ranging from 1800~2000Ma and 1400~1600M, which matched the formation time and splitting time of the Columbia super-continent (Rogers & Santosh, 2002). This data shows that the terrain in the North Tarim region has a certain relationship with the aggregation or cleavage of the Columbia super-continent and the local block may directly come from the super-continent.

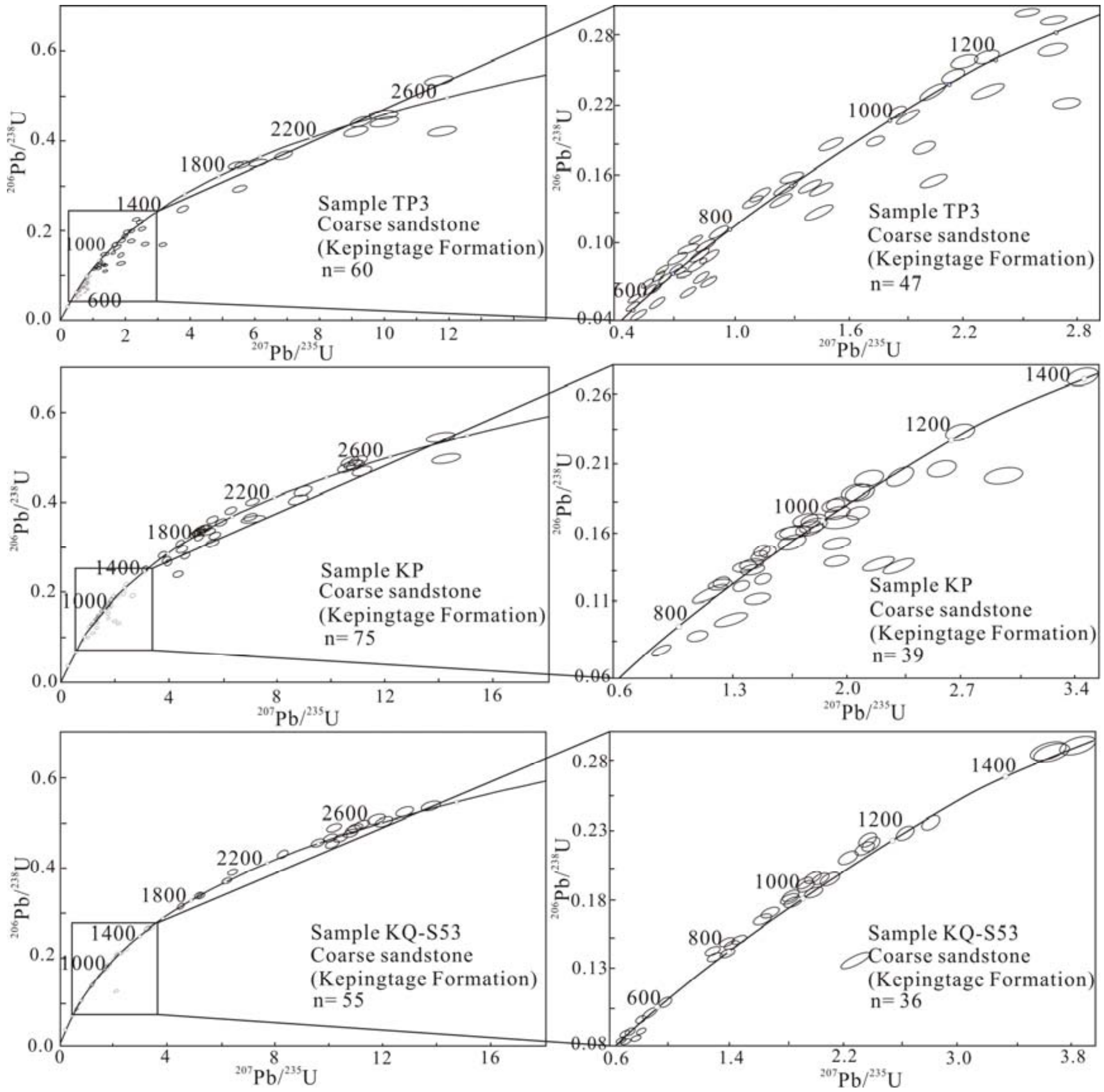

Figure 3. U-Pb concordia plots for zircons from three sandstone samples (KP, TP3, KQ-S53)

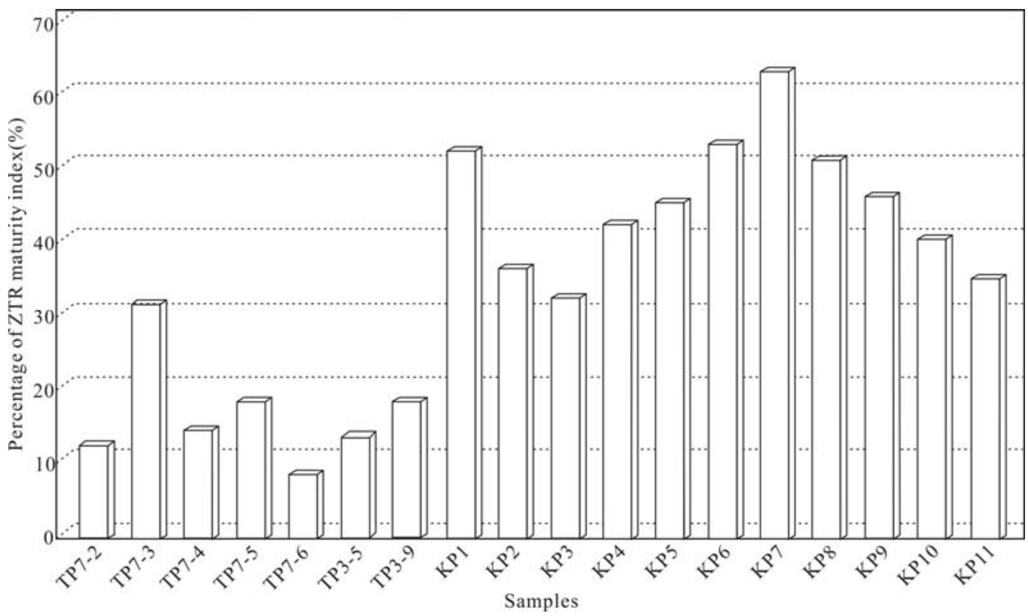

Figure 4. Percentage of ZTR maturity index of the Northern Tarim region

4.2. Geochemistry and petrology of the sandstone

4.2.1. Elements testing

The testing for trace elements and rare earth elements in KP1-KP7 samples from the Keping outcrop show that it contains 44 kinds of elements in the Kepingtage Formation. The variety of elements also greatly varies. For example, there is almost no element of Re found there, while the elements of Ba, Zn, Zr, V, Cr, Ce are often with a content of greater than 100ppm. Zn is the most prevalent element found reaching sometimes 1,203ppm, and the magnitude of changes reached 741.26% (Table 1). The mass fraction of rare earth elements in the sandstone taken from the study area varied quite largely, ranging from 96.7~0.441ppm. Meanwhile, the content of REE (ΣREE) ranged from 224.73~270.06ppm while the ratio of LREE and HREE (LREE/HREE) varied from 8.05~10.47 with the LaN/YbN between 10.96 and 12.68. In addition, the value of δCe was limited to 0.88~0.90 while δE had a range of 0.66 to 0.70. Based on the REE distribution map, it can be found that it has a fractionation of LREE, and the alteration tendency of REE in all samples is very consistent (Fig. 5).

Table 1. Amount of trace elements in sandstone of the Keping outcrop in the Northern Tarim basin (ppm)

Sample	Li	Be	Sc	V	Cr	Co	Ni	Cu	Zn	Ga	Rb
KP1	50.4	2.15	16.1	116	101	17.2	36	57.5	1203	24.6	179
KP2	44.3	1.9	14.8	105	131	16.8	31.6	36	143	23.4	167
KP3	40.7	1.5	11.5	94.4	96.7	15.1	29.9	34.8	301	20.2	136
KP4	43.6	1.77	13.3	109	79.2	14.1	42.4	33	189	22.4	182
KP5	49.9	1.88	13.5	111	82.4	16.7	36	25.8	224	23.7	178
KP6	45.2	1.83	13.6	106	78.7	16.7	30.2	43.6	319	23.6	173
KP7	43.7	1.51	10.2	90.4	89.3	15.5	28.2	22.6	198	21.2	152
Sample	**La**	**Ce**	**Pr**	**Nd**	**Sm**	**Eu**	**Gd**	**Tb**	**Dy**	**Ho**	**Er**
KP1	57	96.7	10.7	38.8	5.72	1.26	5.41	0.91	5.35	1.01	3.34
KP2	56.4	96.1	11.1	42.1	6.74	1.47	5.98	0.97	5.49	1	3.23
KP3	53.5	94.9	11.4	45.3	7.48	1.63	6.47	1.06	5.73	1.03	3.1
KP4	53.5	100	13.2	58.4	12.5	2.63	9.98	1.67	8.45	1.36	3.82
KP5	54.5	94.5	11.3	43.7	6.92	1.48	5.93	0.96	5.51	1.01	3.19
KP6	54	91	10.4	40.5	6.61	1.37	5.93	0.97	5.38	1.02	3.21
KP7	54.1	94.7	10.9	42.6	6.86	1.46	6.11	0.99	5.15	0.915	2.98
Sample	**Tm**	**Yb**	**Lu**	**Y**	**Sr**	**Nb**	**Mo**	**Cd**	**In**	**Sb**	**Cs**
KP1	0.515	3.45	0.531	29.4	91.4	17	0.557	155	0.087	0.979	8.54
KP2	0.514	3.31	0.493	29.6	95.3	15.5	0.778	12.9	0.089	0.335	7.66
KP3	0.48	3.1	0.46	27.7	92.3	15.6	0.744	29.5	0.078	0.421	6.33
KP4	0.542	3.5	0.51	36	97.8	16	1.4	4.05	0.082	0.439	8.34
KP5	0.488	3.21	0.491	27.7	84.3	17.1	0.011	14.6	0.076	1.66	9.05
KP6	0.502	3.35	0.486	30	96	16.3	0.077	27.3	0.083	0.41	8.26
KP7	0.472	3.06	0.441	27.9	94.1	16.4	0.401	10.6	0.074	0.327	7.06
Sample	**Ba**	**Ta**	**W**	**Re**	**Tl**	**Pb**	**Bi**	**Th**	**U**	**Zr**	**Hf**
KP1	579	1.17	3.66	0.001	0.802	798	0.439	16.4	2.72	219	6.05
KP2	555	0.984	5.54	0.001	0.748	63	0.329	15.1	2.69	201	5.44
KP3	544	1.05	4.34	0.001	0.65	189	0.336	13.8	2.44	200	5.34
KP4	525	1.13	1.93	0	0.801	51.6	0.434	16.6	3.07	182	4.99
KP5	632	1.18	2.13	0.001	0.858	104	0.395	16	2.75	195	5.28
KP6	560	1.08	2.28	0	0.763	143	0.388	15.6	2.75	210	5.53
KP7	665	1.06	3.13	---	0.679	67.1	0.281	15	2.51	209	5.84

Sample	ΣREE	LREE	HREE	LREE/ HREE	LaN/ YbN	δEu	δCe	
KP1	230.70	210.2	20.52	10.25	11.85	0.68	0.89	
KP2	234.90	213.9	20.99	10.19	12.22	0.69	0.89	
KP3	235.64	214.2	21.43	10.00	12.38	0.70	0.90	
KP4	270.06	240.2	29.83	8.05	10.96	0.70	0.90	
KP5	233.19	212.4	20.79	10.21	12.18	0.69	0.89	
KP6	224.73	203.9	20.85	9.78	11.56	0.66	0.88	
KP7	230.73	210.6	20.11	10.47	12.68	0.68	0.90	

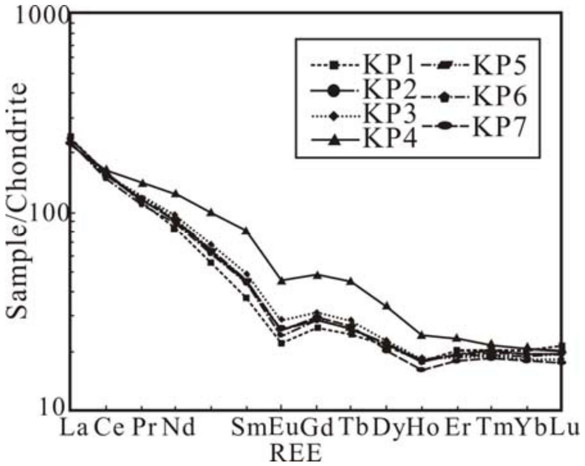

Figure 5. Chondrite-normalized REE patterns for sandstone from the Keping outcrop, Northern Tarim region

4.2.2. Detrital component of sandstone

Two drills in the center of the northern Tarim region (wells TP3 and TP7) and one drill in the west of the northern Tarim region (well KQ1) were used to study their lithological features, and count the percentage of detrital minerals in the wells. The result shows that most of the rocks belonged to lithic sandstone, syrosem quartz sandstone or arkose quartz sandstone and had a high percentage of quartz debris and clastic detritus. Most of the debris has a subangular to sub-rounded shape. The percentage of quartz ranged from 31~87% with a 58% average, most of which was seized by a single crystal quartz (the ratio of Qm and Q range from 51.9~90.6%). In addition, the sandstone contains some heteromorphic quartz like flint and the ratio of Qp and Q ranges from 9.4~47.5%. The content of debris is between 3% and 43% with a 31% average, which is dominated by metamorphic lithic debris (the ratio of Lm and L range from 51.9~90.6%) and volcanic debris (the ratio of Lv and L range from 0~ 33%). There is a development of slight sedimentary debris in the sandstone (the ratio of Ls and L range from 0~19.7%), which is dominated by clay and carbonate rocks. In addition, the content of feldspar is between 7% and 29% with a 12% average, multiple twins and twin cassette are very common. The content of plagioclase is more than the potassic feldspar (P/F range of 70.8~96.0%) (Table 2).

4.2.3. Origin analysis of mother rocks

The quantity of trace elements in rocks can indicate the formation of the tectonic background and a series of trace element diagrams for discriminating tectonic settings has been proposed (Pearce 1982; Pearce et al., 1984; Eby, 1992; Muller, 1992). Bhatia and Cyook (1986) established several trace element diagrams for sandstone to discriminate the tectonic settings in the provenance zone. In this paper, all of the trace element contents are converted into the end percentage and noted as points in Bhatia's La-Th-Sc, Th-Sc-Zr/10 and Th-Co-Zr/10 graphic. The result shows that almost all sample points fall within the scope of a continental island arc (Fig. 6), which indicates that the mother rock of the sandstone in the Keping region of Kepingtage Formation was formed in a continental island arc tectonic setting.

Table 2. Amount of detrital minerals in sandstone of the Kepingtage Formation in some drills in the Northern Tarim basin (%)

Well	Sample	Depth/m	Qm	Qp	Q	K	P	F	L	Lt	Lm	Ls	Lv
TP3	TP3-1	5730.0	78	8	86	2	9	11	3	11	2	0	1
	TP3-2	5729.5	75	11	87	1	6	7	6	18	4	1	2
	TP3-3	5460.8	35	10	45	1	11	12	43	53	42	1	0
	TP3-4	5375.7	46	23	69	1	15	16	15	38	15	0	0
TP7	TP7-1	5910.3	57	16	73	2	5	8	20	35	18	2	0
	TP7-2	5918.5	30	28	57	1	14	15	28	56	22	6	0
	TP7-3	5778.2	36	13	49	0	9	10	41	54	41	0	0
	TP7-4	5799.5	34	25	58	0	8	9	33	58	27	6	0
	TP7-5	5802.3	42	17	59	3	8	11	30	47	29	1	0
	TP7-6	5921.8	41	23	64	3	8	11	25	48	24	1	0
KQ1	KQ1-1	2335.8	42	11	53	2	27	29	19	30	18	1	0
	KQ1-2	2340.0	39	24	63	2	16	18	19	42	19	0	0
	KQ1-3	2342.0	19	13	31	0	8	9	60	73	49	1	10
	KQ1-4	2403.2	22	20	41	1	9	9	49	69	38	1	10
	KQ1-5	2403.8	25	17	42	2	8	10	49	66	39	2	8
	KQ1-6	2406.6	27	18	45	1	6	7	48	66	37	1	10

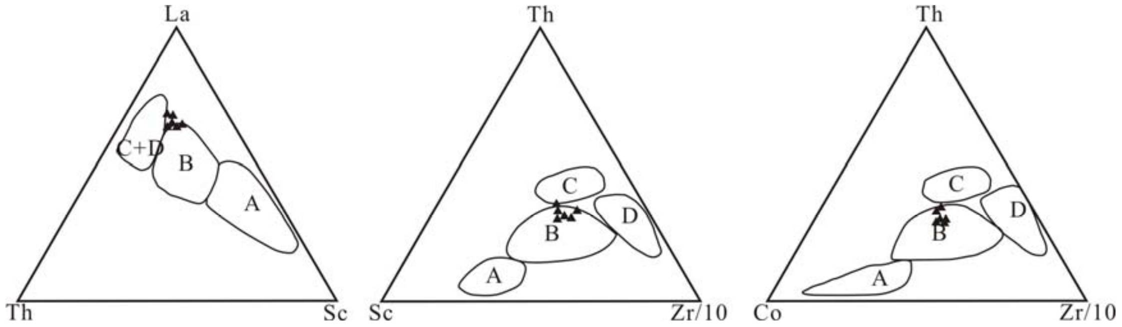

Figure 6. Illustration of structural units according to trace elements in Lower Silurian of Keping outcrop (after Bhatia, 1986). A-Ocean arc; B-Continent arc; C-Active continent margin; D-Passive continental margin.

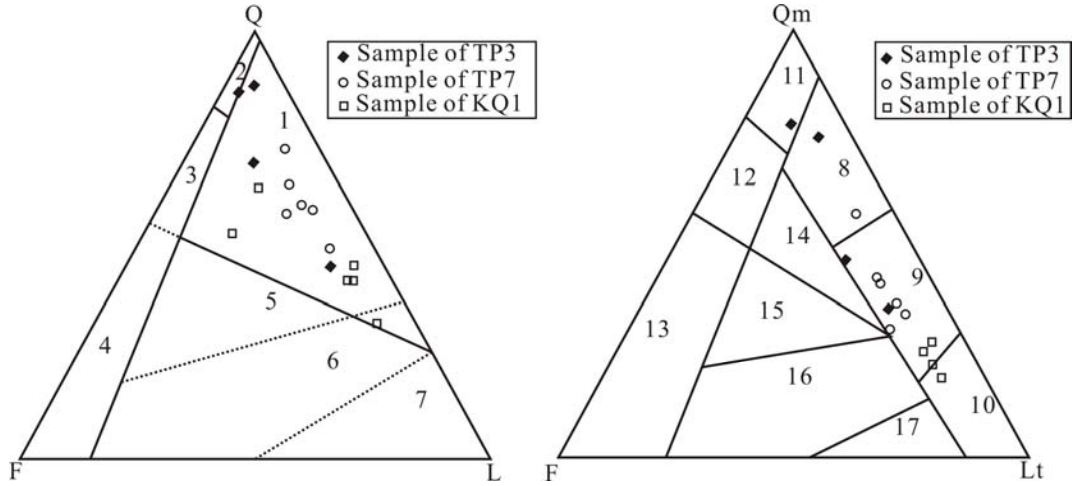

Figure 7. Illustration of structural unit according to QFL in Lower Silurian (left) and QmFLt (after Dickson, 1983). 1-Recycled Orogen; 2-Craton Interior; 3-Transitional Continental; 4-Basement Uplift; 5-Dissected Arc; 6-Transitional Arc; 7-Undissected Arc; 8-Quartzose Recycled; 9-Transitional Recycled; 10-Lithic Recycled; 11-Craton Interior; 12-Transitional Continental; 13-Basement Uplift; 14-Mixed; 15-Dissected Arc; 16-Transitional Arc; 17-Undissected Arc.

Besides, the relative contents of minerals in the sandstone also could be a useful tool to study the forming tectonic setting of mother rocks. The data in table 2 was noted as pointing into the QLF and QmFLt base map established by Dickinson (Dickinson, 1983) and the combination figures represent that the sandstone samples in the central (well TP3 and well TP7) and eastern wells (KQ1) of the northern Tarim region fall on the same tectonic block which is basically due to re-cycle orogenic belt. In addition, all the sample points distributed mixture without accumulation areas, reflecting the consistency of mother rocks (Fig. 7). Therefore, we are aware of the tectonic origin differences of the mother rocks between the western and central (or eastern) region

5. CONCLUSIONS

The Lower Silurian, in the northern Tarim basin features a complex sediment source and deposition. The U-Pb dating of the detrital represented 4 accumulation intervals: 400~600Ma (Late Ordovician), 800~1200Ma (early stage of Late Proterozoic), 1800~2000 Ma (Early Mesoproterozoic) and 2400~2600Ma (late stage of Early Proterozoic). Sandstone in the Keping area was dominated by Precambrian mother rocks while the central and eastern region was controlled by Ordovician mother rocks. The dating of the detrital zircon indicates that the Tarim plate is a part of the Rodinia supercontinent during the Neoproterozoic and the Caledonian event in Late Ordovician which caused the formation of Kuluketage provenance. The time period of the micro-blocks in the north Tarim region may be consistent with the aggregation or cleavage of the Columbia super-continent. The Lower Silurian sandstone in Northern Tarim regions came from two directions. The sediment in the Keping region was from the Precambrian basement in the Kuqa area while the one in the central and eastern regions came from the Kuruketage region which rose during Late Ordovician. The mother rock of the Lower Silurian in the Keping area formed in a continental island arc tectonic context while the one in the central and eastern part of the north Tarim region formed in a recycle orogen tectonic setting.

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