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Textural Characterization of Sedimentary Zircon and Its Implication

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1. Introduction

Zircon with highly refractory, as accessory, detrital minerals occurs in virtually all sediments and sedimentary rocks, has played a prominent and complex role in interpreting the history of sediments and source history of a deposit, paleogeography, and tectonic reconstructions (Qian Y.X., et al., 2007a). The main use of CL imaging of Detrital zircon has been as an adjunct to U-Pb dating of zircons, which allows identification of different types of zircon domains, then may be dated in situ within a spatial resolution of about 15~30 μm. By using a SHRIMP (Sensitive High-Resolution Ion Microprobe), this data analysis would be a powerful tool in understanding origin of the zircon, that is, the various geological processes (magmatism, deposition, metamorphism, hydrothermal alteration, metasomatic leaching of Th, U, and Pb), their surrounding source terrane of known age may be traced and a geological evolution history of sedimentary basins may be established. In fact, the analyzed sample wouldn't completely represent geological history by including evidence of all the possible provenances and their relationships to each other due to natural complexity of sample. It was mentioned that the analysis techniques involve the sampling protocol and interpretation of data and then show the application of detrital zircon studies to: (1) analysis of origin characteristics such as U-Pb isotopic analysis and composition, (2) determine on the using age of stratigraphic successions and to help recognize time gaps in the geologic records, (3) test regional paleogeographic reconstructions by origin analysis, and (4) reveal geological history relative with the mineral chemistry of detrital zircon, and reveal complexity in order to gain insight into natural processes.

2. Analysis of origin characteristics such as U-Pb isotopic data and composition

The distribution of heavy minerals in sediments is affected by the following factors: provenance, uplift and erosion, paleo-topographic feature, palaeo-climate and palaeo-environment. The analysis of heavy minerals can be applied in explanation of the sedimentary response to tectonic cycles based on the provenance and sedimentary environment.

The heavy minerals assemblage can be act as indicators of provenance. The assemblage of zircon, tourmaline, apatite and little biotite with the well-development crystal shapes is

generally believed to come from granitic rocks; the assemblage of a great quantity of Garnet, zircon, epidote, chlorite is derived from metamorphic rocks; while the assemblage of magnetite, ilmenite, anatase, augite and hornblende is commonly be readily traced to balt-igneous rocks. In addition, the characteristic of heavy minerals are not only indictor of the composite of provenance, but also of physical-selection, mechanical abrasion of granular and chemical dissolution of sedimentary rocks during the process of sedimentary and transportation. Based on the primary analysis of sandstones with regard to sedimentary environment and provenance, five heavy minerals assemblages can be reasonable classified as follows: ①stable minerals assemblage: includes the most of Ti oxide , zircon and Tourmalie; ②the relative stable minerals assemblage: predominantly composes of garnet and apatite; ③un-stable minerals assemblage: be dominated by epidote · augite and Hornblende; ④the assemblage of the indication of initial depositional environment :be associated with hematite, pyrite, glauconite, barite, and carbonate minerals; ⑤ore minerals present in hydrothermal mineralization. In addition, the index of ZTR, which shows the percent of zircon, toumalie, rutile, and oblique carbonate minerals in heavy minerals assemblage, the high value ZTR, the great maturity of heavy mineral.

3. Reveal geological history relative with the mineral chemistry of detrital zircon, and reveal complexity in order to gain insight into natural processes

The mineral zircon is extremely variable both in terms of external morphology and internal textures. These features reflect the geologic history of the mineral, especially the relevant episode(s) of magmatic or metamorphic crystallization (and recrystallization), strain imposed both by external forces and by internal volume expansion caused by metamictization, and chemical alteration. One of the major advantages of zircon is its ability to survive magmatic, metamorphic and erosional processes that destroy most other common minerals. Zircon-forming events tend to be preserved as distinct structural entities on a pre-existing zircon grain. Because of this ability, quite commonly zircons consist of distinct segments, each preserving a particular period of zircon-formation(or consumption).

In common rocks, zircon ranges in size from about 20 to 200 μm .The elongation (length-to-width) ratios is ranging from 1 to 5. which is commonly believed to reflect crystallization velocity. Indeed, needle-shaped acicular zircon crystals are common in rapidly crystallized, porphyritic, sub-volcanic intrusions, high-level granites, and gabbros. In addition, newly-grown zircon crystals can themselves exhibit evidence for multiple stages of growth and corrosion.

Sedimentary rocks may also contain a significant fraction of zircon. Although authigenic zircon has been reported, sedimentary zircon is predominantly derived from weathered igneous and metamorphic rocks. Detrital zircon in sedimentary rocks and sediments is highly durable and records age information of crustal units that contributed to the sediment load.

The External morphologies of zircons in heavy minerals are included the followings: colors, opaque, lustre, roundness, coarse, dissolution, abrasion and elongation, based on the its roundness of grains, which is to unravel the transportation distance of sediments, which has been attributed to its provinces, two subgroups are classified as:

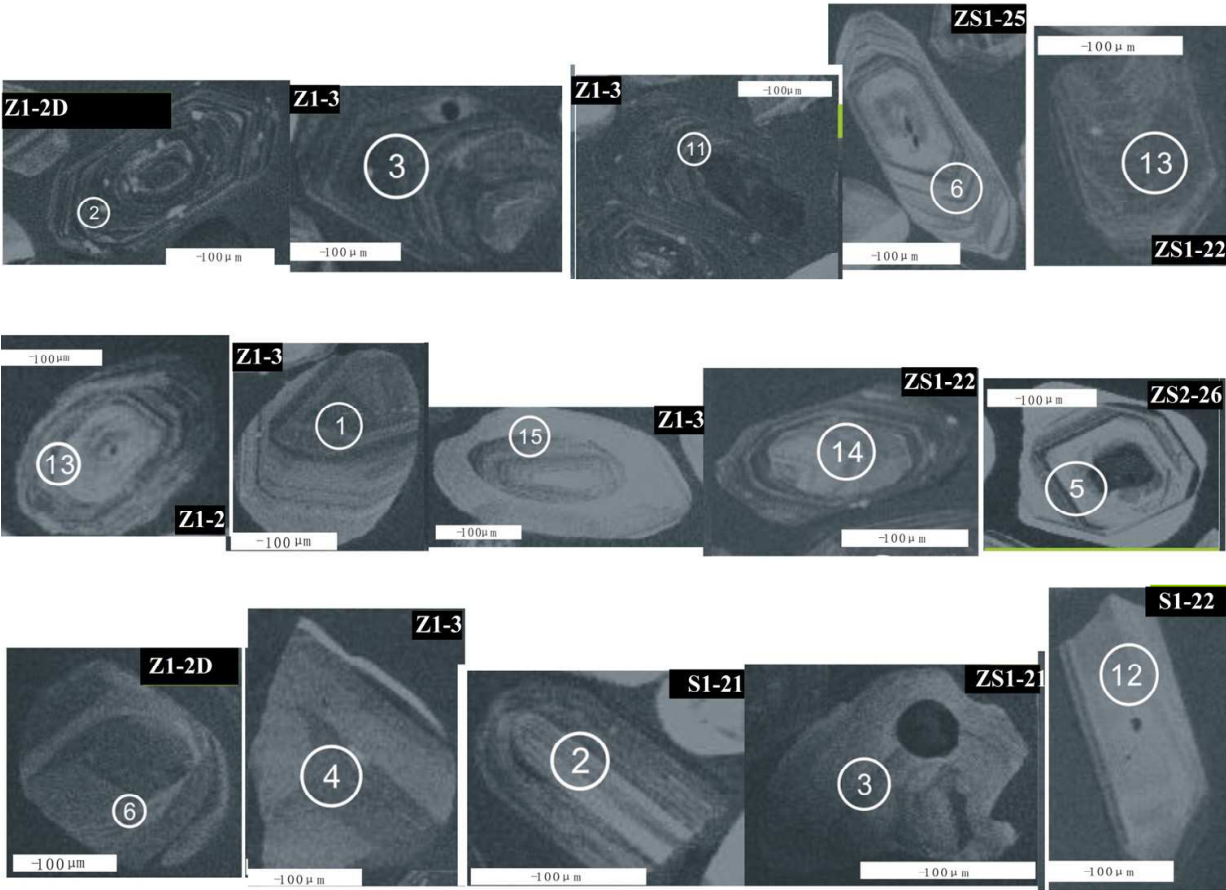
1. Zircons with a high degree roundness: which are mostly consist of dark pink-rose with few of yellow-pink colors ,sub-opaque , coarse glass luster, and sub-rounded and rounded grains with obvious relics of abrasion , with elongation (length-to-width) ratios ranging from 1 to 2, and preferential growth of grains 0.05mm~0.2mm , in response to transportation of sediments
2. Zircons with a medium degree roundness: : which are dominantly composed by sub-opaque or opaque, weak-diamond to coarse glass luster, pink-shallow pink colors and sub-rounded and rounded grains, euhedral with obvious relics of abrasion of mostly grains with few smooth surface of grains , with elongation (length-to-width) ratios ranging from 1.5 to 3.5 and with a size from 0.05mm~0.35mm in diameter of grains , the grains with a rather high round would be taken a great parts among all of grains with a well selection, indicating the obvious transportation of sediments °

In simple way, three different types of detrital zircons would be termed :

1. the igneous zircon with six- prismatic concentric zone (Fig.1);
2. Metamorphic zircon with a internal structure of core-mantle-rimmed; either the core-mantle-rimmed or the core- rimmed commonly appears to developed in metamorphic zircon with a different component of core, mantle and rim(Fig.1). The origin and inherit zircons may be observed in the core part of grain of zircon, while the metamorphic zircons grows in the mantle or rimmed(Hermann et al. , 2001) ; equant and weak zoning zircons are not likely to occur in granulite rocks; it is not uncommon to find zircons with a fan-shape and oscillatory zoning in the process of serpentinization of basic and ultra basic rocks , the zircons can retain a plane zoning in response to the metamorphic re-crystallization either in re-melting migmatite or in a neocryst of ovoid shape(Fig.1);
3. re-cycle sedimentary zircons with a feature of cathodoluminescence (CL) or no growth zoning and metamict zones(Fig.1).

The zircons in the Lower Silurian sandstones, well Shun1 also shows the difference among the samples, for example, 15 percent, the most lowest content of six- prismatic concentric zone, 71 percent, the highest content of non-zoning and 33 percent, the rather high cathodoluminescence (CL) are presented in Shun1-21 ; indicating the stable re-cycle sedimentary environment; while 20 percent of six-prismatic concentric zone , 33 percent of structure of core-mantle-rimmed ,48 percent of non-zoning, and 25 percent of cathodoluminescence (CL) in Shun1-22, illustrated that igneous and metamorphic zircon has been majorly attributed to the detrital zircons(Fig.2).

It would be reasonable predicted that unaltered igneous zircon generally contains the highest contents of U , Th and Pb, which is a comparable to that of Metamorphic zircon and Re-cycle sedimentary zircons, and the re-cycle sedimentary zircons would be various in contents between the igneous zircon and Metamorphic. U as a un-compatible element, would be accumulated in anatectic melting crystallization and partial differentiation; while the contents for U and Th decreased in the metamorphic process due to being dispelled from the crystal lattices during the re- crystallization in solid. In addition, the contents for Pb is supposed to relate the contents of U and Th and age of rocks, the higher of contents of U and Th and the older of age of rocks; the greater of the accumulated content of radiogenic lead in zircons.



1. Alteration developed along concentric fractures parallel to the boundary between the low-U interior part of the zircon and the high-U outer shell; an outermost low-U rim has radial cracks, which have allowed the access of the fluids(Z1-2(D); Partially preserved growth zoned zircon penetrated by transgressive zones of recrystallization and with local development of recrystallization or convolute zoning (ZS2-25);
2. Recrystallization and new growth of zircon in high-grade metamorphic rocks, Bands or other large segment of homogeneously textured zircon (ZS2-26); strong variations in the relative development of zoned domains, large uniform zone external and much finer oscillatory-zoned bands in internal structure (Z1-3)
3. Late to post-magmatic recrystallization of zircon, Variable appearance of xenocrystic cores in magmatic (Z1-2D,ZS-2)and high-grade meta-morphic rocks(Z1-3,ZS2-26),Z1-2(D),Z1-3); Variations in growth zoning in magmatic zirconAppearance and texture of zircon in meteorite impact structures(ZS1-21);

Fig. 1. Typical Zircon CL structures for different origin and SHRIMP U-Pb Concordia plots with spot locations, from Donghe sandstones of DongheTang formation, the Upper Devonian in western Tazhong area , or the Lower Silurian sandstones ,Tarim basin: igneous zircons(upper),Metamorphic zircon(Middle),Re-cycle sedimentary zircons(down),different scales in zircon megacryst,ranging from 0.5 mm down to a few 50um.

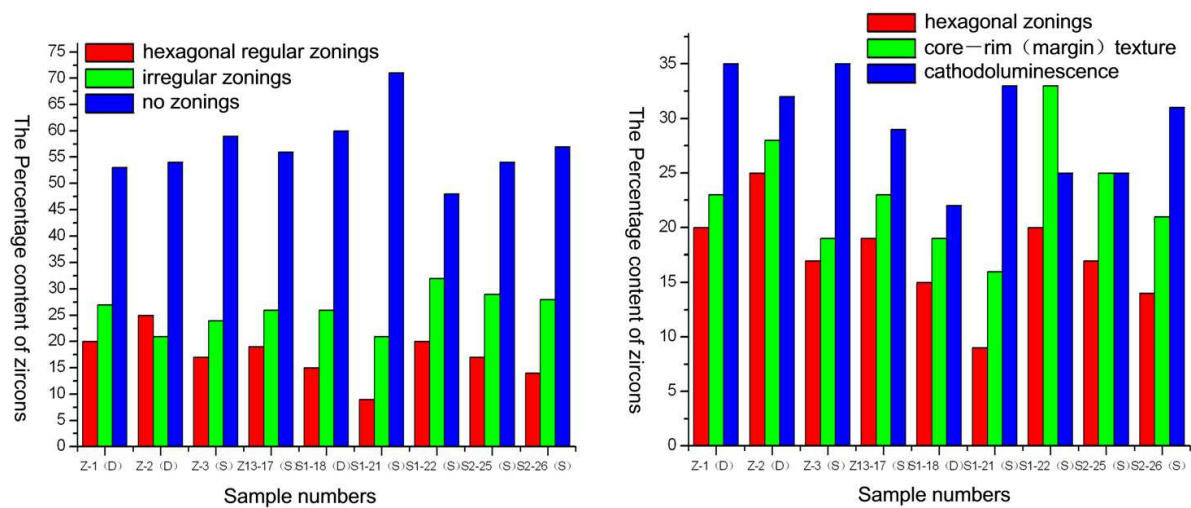


Fig. 2. Diagram showing the statistics of typical Zircon grains based on their sources from Donghe(lift)and the Lower Silurian sandstones(right) in wells of Zhong1,11,12,13 and Shun1,2. Tarim basin (Qian Y.X.,et al.,2007b)

4. Determine maximum age of stratigraphic successions and to help recognize time gaps in the geologic records

The most reliable means of directly determining depositional sedimentary ages is through the dating of interstratified volcanic rocks, or dating time-of-deposition authigenic xenotime overgrowths on detrital zircon grains (Mc Naughton *et al.* 1999). Under certain circumstances, the age of the youngest detrital zircon in a population can approach the age of deposition (Nelson, 2001). Disconformities reveal information about coeval tectonics/uplift and sea-level fluctuations. In the absence of fossils to identify gaps in the geologic record.

The results are typically the U-pb isotopic data of zircon from sensitive high resolution ion microprobe(SHRIMP)analyses can provide the accurate age constrains for record of events associated with the major geodynamic evolution of stage from Proterozoic to the Early Paleozoic in Tarim basin and its surrounding orogenic belts.

The U-pb isotopic data of zircons can be divided into three groups , i.e. 1.8Ga,2.2Ga and 2.6Ga from Meso-Proterozoic to Neo- Proterozoic; 0.84Ga in Cambrian; and 477~439.8Ma and 431.6~421.1Ma from Ordovician to The Lower Silurian(Fig.3), which have a concordance with the records of rocks derived from that of wells or outcrops of Tarim basin and its surrounding orogenic belts.

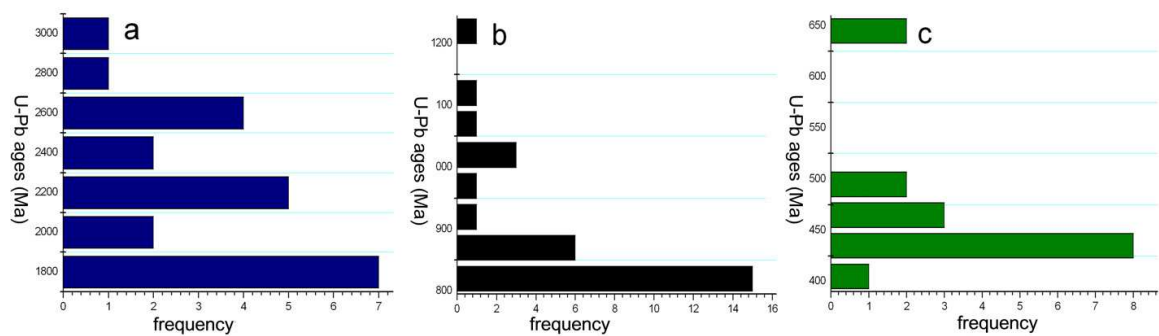


Fig. 3. Frequency histograms for Distribution of $^{206}\text{Pb}/^{238}\text{U}$ ages of Zircon from Proterozoic(a) to Neo-Meso Proterozoic(b) and Paleozoic(c) in western Tazhong area ,Tarim basin

5. Test regional paleogeographic reconstructions by origin analysis

Previously published research from the Kuqa Sub-basin along northern margin of the Tarim Basin shows five tectonic-depositional phases from Triassic to Neogene time (Li *et al.*, 2010). In order to reveal more detailed information on the nature of provenance terrains and tectonic attributes since late Mesozoic time, five typical sandstone samples from Jurassic Neogene strata were collected for U-Pb dating of detrital zircons.

Geochronological constitution of detrital zircons of the Middle Jurassic sample is essentially unimodal and indicates major contributions from the South Tian Shan, wherein most 370~450Ma zircons probably resulted from tectonic accretion events between the Central Tian Shan block and South Tian Shan Ocean during Silurian and Devonian time, with sandstone provenance tectonic attributes of passive continental margin. The Lower Cretaceous sample shows a complicated provenance detrital zircon signature, with new peak ages of 290~330Ma as well as 370(or 350)~450Ma showing evidence of arc orogenic provenance tectonic attribute, probably reflecting a new provenance supply that resulted from denudation process within the South Tian Shan and South Tian Shan suture. There are no obvious changes within age probability spectra of detrital zircons between the Cretaceous and early Paleogene samples, which suggests that similar provenance types and basin-range framework continued from Cretaceous to Early Paleogene time. However, unlike the Cretaceous and early Paleogene samples, an age spectra of the Miocene sample is relatively unimodal and similar to that of the Pliocene sample, with peak ages ranging between 1392 and 1458Ma older than the comparable provenance ages (peak ages about 370~450Ma) of the Middle Jurassic and Lower Cretaceous samples. Therefore, we can conclude that the South Tian Shan was rapidly exhumated and the southern South Tian Shan had become the main source of clastics for the Kuqa Sub-basin since the Miocene epoch. and the corresponding age-probability plots in Fig.4.

We contrast the detrital zircon age spectra from the Kuqa Subbasin with those of potential provenance areas, discussing the implications for provenance and paleogeographical changes. Detrital zircons of the Middle Jurassic sample mostly range from 370 to 450Ma, with a small number of Proterozoic-Archean ages. This geochronological constitution is comparatively unimodal and indicates that the dominant source of detritus was likely from the northern South Tian Shan and southern Central Tian Shan (Fig.5), probably resulting from tectonic accretion events between the Central Tian Shan Block and the South Tian Shan Ocean that occurred during Silurian and early Devonian time, with dominant sandstone provenance tectonic attributes of passive continental margin discriminated by major element composition of whole-rock samples. The Lower Cretaceous sample shows a provenance with complicated detrital zircon age spectra, with new peak ages of 290-330Ma as well as 370 (or 350)-450Ma. Reflecting a new provenance supply produced by denudation of the South Tian Shan and South Tian Shan suture. These grains likely reflect Carboniferous-Permian volcanism and the Silurian-Devonian tectonic events between the South Tian Shan-Tarim and Central Tian Shan blocks, with dominant sandstone provenance tectonic attributes of active continental margin or island arc (arc orogenic belt). In addition, several clusters of Proterozoic-Archean ages from this sample probably reflect that some provenance regions may have been deeply exhumated. The lack of obvious changes in detrital zircon age probability spectra between the Cretaceous and early Paleogene samples suggests that similar provenance types and basin-range framework likely continued from Cretaceous to early Paleogene time (Fig. 5).

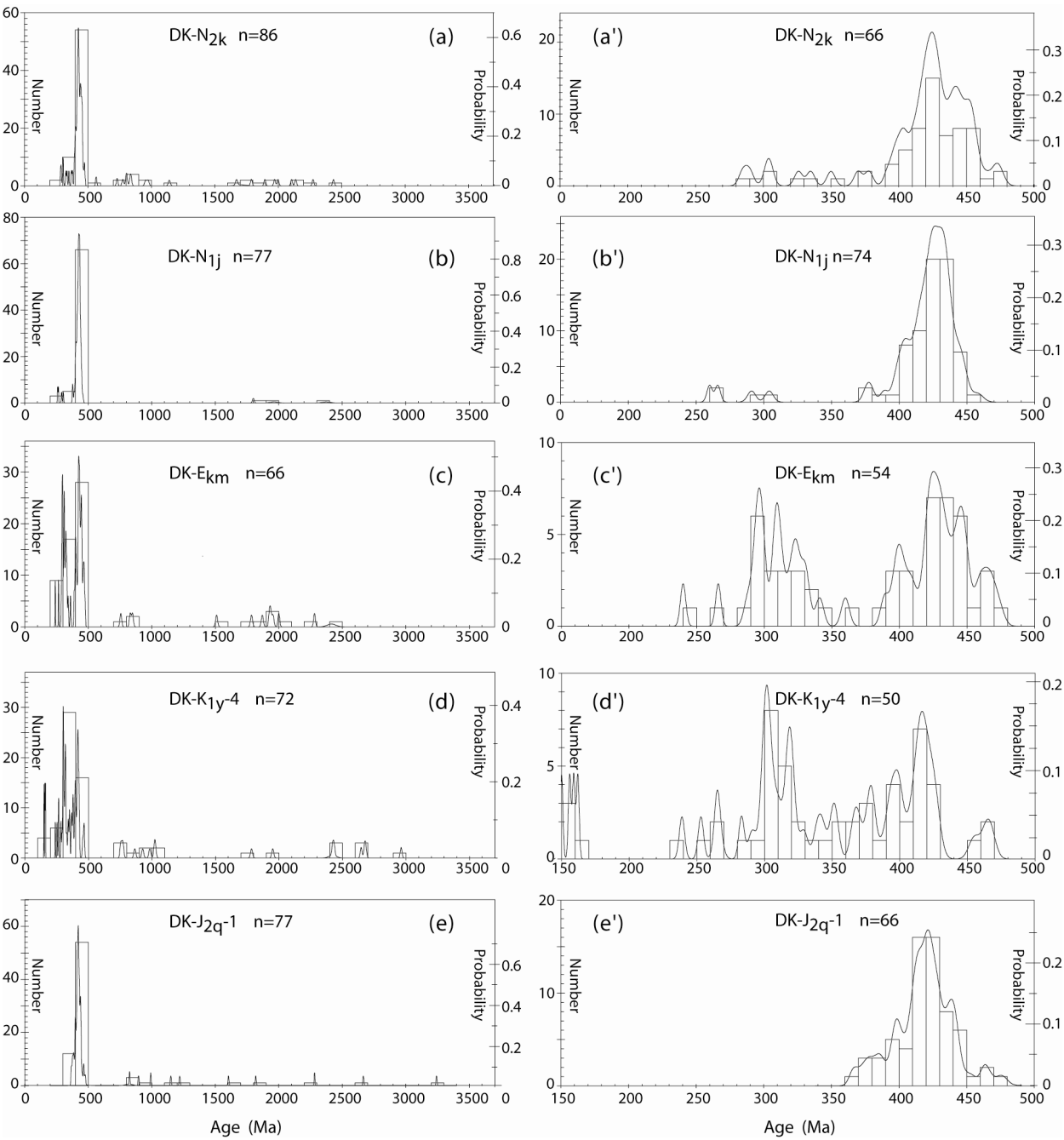


Fig. 4. Probability plots and number histograms of U-Pb ages of detrital zircons from Middle Jurassic-Neogene sandstone samples in Kuqa Subbasin. (a)-(e) 0-3700Ma grains; (a0)-(e0) 150-500Ma grains(after Li *et al.*,2010).

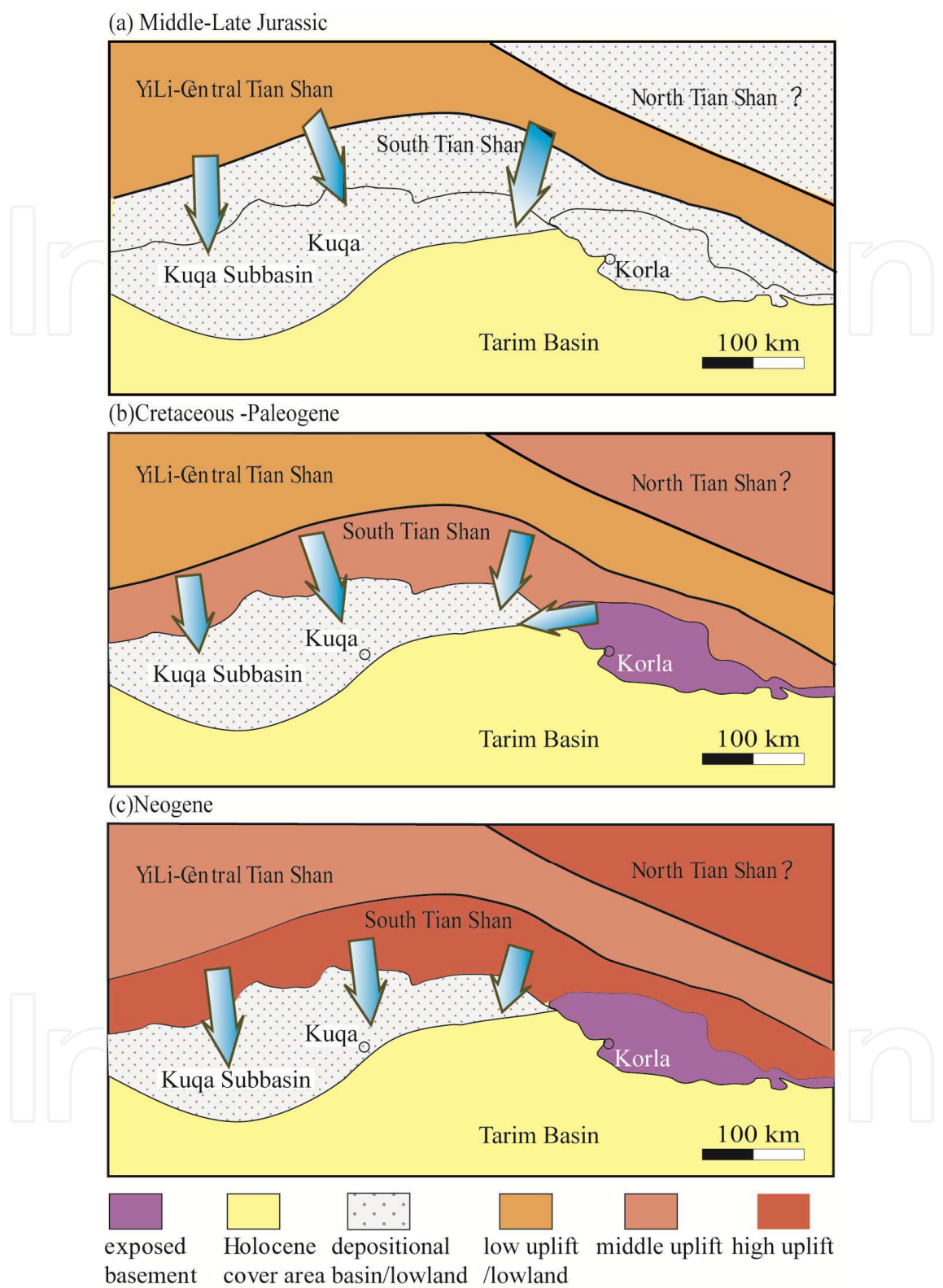
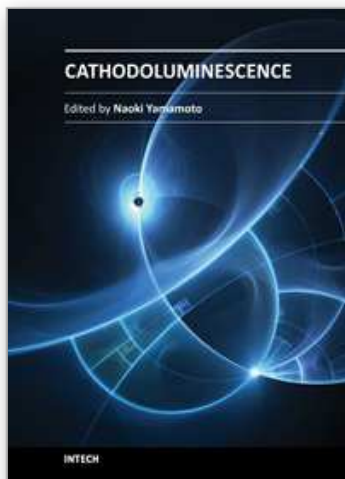


Fig. 5. Schematic map showing major provenance area changes from middle Jurassic (a), through Cretaceous-Paleogene (b), to Neogene (c). Arrowheads, with width, indicate directions, power and ranges of major inferred provenance supply. Structural deformation and intra-continental shortening that occurred in the study area from Jurassic to Neogene is ignored on the above maps(after Li *et al.*,2010)

6. References

- Li, Z., Peng, S.T. (2010) Detrital zircon geochronology and its provenance implications: responses to Jurassic through Neogene basin-range interactions along northern margin of the Tarim Basin, Northwest China. *Basin Research*, 22 : 126~138
- Mc Naughton NJ, Rasmussen B, Fletcher IR (1999) SHRIMP uranium-lead dating of diagenetic xenotime in siliciclastic sedimentary rocks. *Science*, 285:78-80
- Nelson DR (2001) An assessment of the determination of depositional ages for Precambrian clastic sedimentary rocks by U-Pb dating of detrital zircon. *Sed geol*, 141-142
- Qian Y.X., He Zh.L., Cai X.Y., *et al.* (2007a) Characteristics of heavy minerals from Upper Devonian Donghe sandstone and Silurian sandstone in western Tazhong area , Tarim Basin , and their geological implications. *Acta Petrologica et Mineralogica*, 26(2) : 147~154 (in Chinese)
- Qian Y.X., He Zh.L., Cai X.Y., *et al.* (2007b) Characteristics of and U-Pb ages of zircons and its implication from zircon of Donghe sandstones of The upper Devonian and Silurian sandstones in Tazhong area, Tarim basin. *Acta Petrologica Sinica*, 23(11) : 3003~3014 (in Chinese)

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Cathodoluminescence (CL) is a non-destructive technique to characterize optical and electronic properties of nanostructures in many kinds of materials. Major subject is to investigate basic parameters in semiconductors, impurities in oxides and phase determination of minerals. CL gives information on carrier concentration, diffusion length and life time of minority carriers in semiconductors, and impurity concentration and phase composition in composite materials. This book involves 13 chapters to present the basics in the CL technique and applications to particles, thin films and nanostructures in semiconductors, oxides and minerals. The chapters covered in this book include recent development of CL technique and applications to wide range of materials used in modern material science.

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