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Diversity of uranium deposits in China – An introduction to the Special Issue

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ABSTRACT

As one of the top ten countries with important uranium resources, China hosts most of the fifteen types of uranium deposits identified by International Atomic Energy Agency (IAEA), among which the economically most important ones are sandstone-type, granite-type, volcanic-type, and carbonaceous-siliceous-pelitic rock- or carbonate-type. This Special Issue provides an up-to-date perspective of the geological characteristics, metallogenic environments, ore-forming mechanisms and exploration methods by the Chinese uranium geoscience community, of the more important types of uranium deposits in China. Among the fourteen papers, six are on sandstone-type, two on volcanic-related, two on granite-related, two on intrusive-type, one on carbonaceous-siliceous-pelitic rock-type or carbonate-type, and one on IOCG or polymetallic iron oxide breccia complex-type. These papers provide useful references for comparison between the Chinese uranium deposits and their counterparts in other parts of the world, and will contribute to further advancement of the global uranium geoscience and resource exploration.

Uranium is an element that can be active in various geological environments and can be accumulated to form mineral deposits of economic significance at conditions ranging from magmatic, metamorphic, hydrothermal, sedimentary to near-surface, resulting in an extreme diversity of uranium deposits (Cuney, 2009). The classification of uranium deposits has been evolving through the years, and according to IAEA (2018a), uranium deposits may be classified into 15 types based on their geological characteristics: 1) intrusive, 2) granite-related, 3) polymetallic iron oxide breccia complex, 4) volcanic-related, 5) metasomatite, 6) metamorphite, 7) Proterozoic unconformity, 8) collapse breccia pipe, 9) sandstone, 10) paleo quartz-pebble conglomerate, 11) surficial, 12) lignite-coal, 13) carbonate, 14) phosphate, and 15) black shale, many of which can be further divided into sub-types. The top ten countries that occupy most of the uranium resources (about 82.3%) in the world are Australia (28.9%), Kazakhstan (11.51%), Russia (8.57%), Canada (8.37%), Niger (6.86%), Namibia (6.48%), South Africa (5.73%), Brazil (4.68%), USA (3.51%) and China (3.37%) (Cai et al., 2015 and references therein). The sandstone-, granite-related, and volcanic-related types have reasonably assured uranium resources (RAUR) accounting for 26%, 6% and 3%, respectively, of the total. According to NEA and IAEA (2018), the identified recoverable uranium resources of China as of January 2017 range from 101,200 to 290,400 tonnes U, and the in-situ uranium resources range from 127,800 to 370,900 tonnes U, depending on uranium prices (from <$40 USD/kgU to <$260 USD/kg U), placing China in the 10th position in the world. At present, China possesses most (about 1/3) nuclear power units under construction in the world, but nuclear power accounts for only 3% of the total energy production in China, far below the average 11% in the world (IAEA, 2018b). Hence, nuclear power is a very important potential energy in China which demands huge uranium resources in the future.

Most of the types of uranium deposits classified by IAEA (2018a) can find examples in China, although sometimes under different names; for example, the so-called carbonaceous-siliceous-pelitic rock-type uranium deposits in China may be compared to the carbonate type in some cases or the black shale type in others (Min, 1995; Hu et al., 2008; Li et al., 2019). Among the various types of uranium deposits (Fig. 1), the economically most important ones in China are sandstone-type (43%), granite-type (22.9%), volcanic-type (17.6%), and carbonaceous-siliceous-pelitic rock- or carbonate-type (8.7%), which account for

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more than 92.2% of RAUR in China (Huang et al., 1994; Hu et al., 2008). The total metal uranium reserves of the other types of uranium deposits including intrusive (e.g., alkaline rock-carbonatite, pegmatite), lignite, pelite, and phosphorite are about 7.8% of RAUR in China. From the mid-1950 s to late-1980 s, the exploration of uranium mainly targeted the volcanic-related and granite-related uranium deposits developed in the tectono-magmatic belts in South China, which led to the discoveries of many important deposits. With the introduction of in-situ leaching (ISL) mining method to China since the 1990s, an exploration climax for sandstone-type uranium deposits hosted by sedimentary basins in North China has emerged. As a result, numerous large and superlarge sandstone-type deposits have been found, and new discoveries are being made. The breakthrough of exploration on sandstone-type uranium deposits has totally changed the distribution of uranium resources in China.

Different types of uranium deposits in China show apparent temporal-spatial patterns, distinct mineralizing processes and host rocks, and particular metallogenetic settings. The U ore deposits of various types in China are largely concentrated in the Paleo-Asian metallogenic realm, the Qin (Qinling)-Qi (Qilianshan)-Kun (Kunlunshan) metallogenic realm, the Circum-Pacific metallogenic realm, and the Tethyan metallogenic realm, respectively (Fig. 1). Sandstone-type uranium deposits, which were the result of large-scale transportation of uranium-bearing oxidizing fluids associated with the evolution of the Paleo-Asian and Circum-Pacific tectonic domains, are predominantly hosted by Mesozoic to Cenozoic continental basins, mainly in North China and some in southwest China. Volcanic-related and granite-related uranium deposits were mainly formed within the Indosinian to Yanshanian (Late Mesozoic) tectono-magmatic belts in South China, with some generated in both the Middle-Lower Yangtze River and Qin-Qi-Kun tectono-magmatic belts. The formation of these two deposit-types is most likely related to the large-scale magmatic emplacement and volcanism and associated deep processes such as crust-mantle interaction induced by the development of the Circum-Pacific and/or Tethyan tectonic domains, although their association with sedimentary basins has also drawn some attention. Carbonaceous-siliceous pelite-type uranium deposits are mainly distributed along the margin of the Yangtze Block, South China and subordinately in the southern Qinling Orogen of Central China. This deposit-type, which most likely was related to the evolution of the Tethyan tectonic domain, is hosted by the Late Neoproterozoic to Permian marine carbonates and fine-grained clastic sedimentary rocks. Despite a relatively small output, intrusive- and IOCG (hydrothermal iron oxide-Cu-Au-U-REE) types have been recognized in the Qin-Qi-Kun and Kangdian metallogenic belts, respectively (Fig. 1). It is of great significance particularly for the latter type, because it indicates that U can be associated with other metals (e.g., REE, W, Sn, Bi, Mo, Re, PGEs, Au, Ga, Ge, In, Nb, Ta, Co, Ni, V, and Cu, Pb, Zn, Mn) in other metallic ore deposits.

The Special Issue on URANIUM DEPOSITS IN CHINA aims at: 1) systematically summarizing the geological characteristics and metallogenic environments of the different types of uranium ore deposits, 2) understanding the metallogenic processes and ore-forming mechanisms of the different types of uranium ore deposits, 3) introducing the newest exploration methods and techniques used by the Chinese uranium geoscience community to the world, 4) presenting the advancement of exploitation and utilization of the Chinese uranium resources, and 5) providing references for comparison between the Chinese uranium deposits (and their classifications) to other parts of the world. Therefore, the papers published in this Special Issue are fairly representative of the different types of uranium deposits in China. Among the fourteen (14) papers, six are on sandstone-type (Chen et al., 2020; Su et al., 2020; Nie et al., 2020; Shi et al., 2020; Wang et al., 2020a, 2020b; Zhang et al., 2020), two on volcanic-related (Deng et al., 2020; Guo et al., 2020), two on granite-related (Chi et al., 2020; Wang et al., 2020a, 2020b), two on intrusive-type (Chen et al., 2019; Cai et al., 2020), one on carbonaceous-siliceous-pelitic rock-type (Li et al., 2019), and one on IOCG or polymetallic iron oxide breccia complex-type (Song et al., 2020).

The papers on sandstone-type uranium deposits in this Special Issue cover a wide range of topics from tectonic, stratigraphic, diagenetic, petrological, mineralogical, geochemical, thermochronological, hydrogeochemical, to in-situ leaching. It is generally agreed that tectonic evolution plays an important role in the sedimentary and diagenetic history of sedimentary basins, which in turn control the host rocks and geochemical conditions for uranium mineralization. In the paper entitled "Late Cretaceous-Cenozoic tectonic-sedimentary evolution and U-enrichment in the southern Songliao Basin", Wang et al. (2020a), Wang et al. (2020b), based on mineralogical study, apatite fission-track (AFT) analysis and SEM-CL analysis of quartz grains, divided the uranium mineralization in the Songliao Basin into a pre-enrichment stage during the Late Cretaceous, in relation to rapid uplift of the Great Xing'an Range and the Zhangguangcai Range and a post-rift environment in the Songliao Basin, followed by an ore-forming stage from the Late Cretaceous to Cenozoic in relation to hydrocarbon reconcentration, in the structural inversion phase of the basin. Zhang et al. (2020), in the paper entitled "Relationships between Meso-Cenozoic denudation in the Eastern Tian Shan and uranium mineralization in the Turpan-Hami

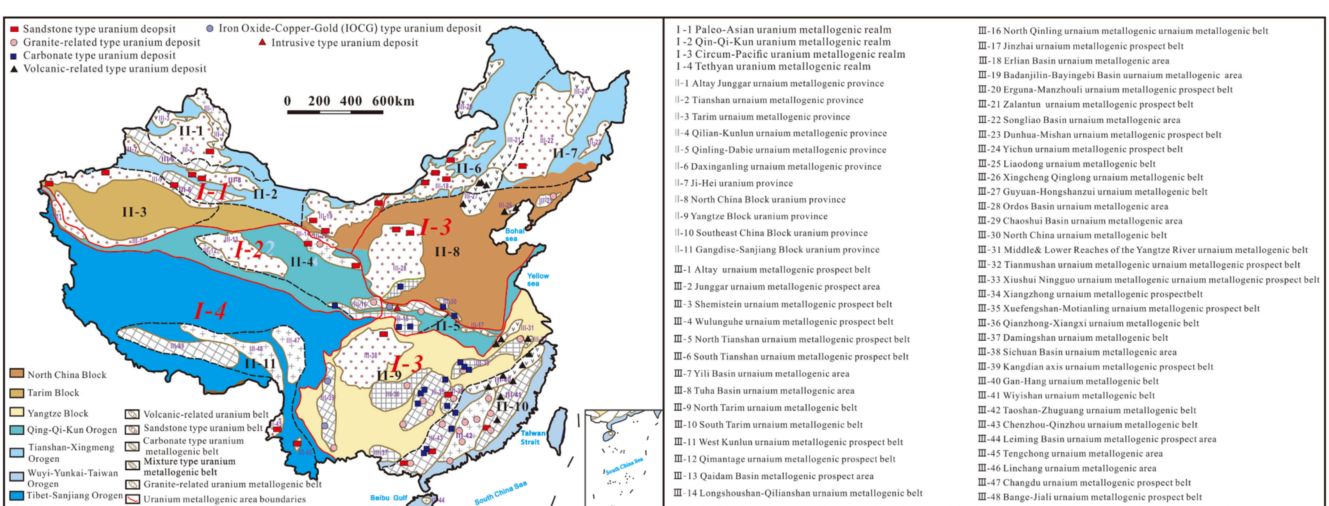

Fig. 1. Sketch map showing main U ore deposits, U ore-deposit types and U metallogenic realms and belts/areas in China (modified from Zhang et al., 2012; Cai et al., 2015).

basin, NW China: Constraints from apatite fission track study", conducted an apatite fission-track study of samples from the Eastern Tian Shan Orogen and linked the uranium mineralization in the Turpan-Hami (Tuha) Basin with denudation history of the orogen from Late Jurassic to Early Miocene. They propose that the uranium mineralization in the Tuha Basin was mainly related to exposure of U-bearing volcanic rocks on the surface in the mountains south of the basin during the Cretaceous, and that the sedimentation during the Cenozoic, mainly sourced from the mountains north of the basin, served as protection to preserve the uranium deposits. Nie et al. (2020), in the paper entitled "Genetic models and exploration implication of the paleochannel sandstone type uranium deposits in the Erlian Basin, North China- A review and comparative study", summarized and discussed the multiple styles of paleochannel sandstone-type uranium deposits in the Erlian Basin and their controlling factors, including regional geological settings, depositional facies and sequences, ore-bearing sand bodies and uranium source rocks. They propose that there was a hydrothermal mineralization event, which may be related to deep-seated faults, overprinting interlayer oxidation mineralization.

Elevated temperatures (greater than100 °C) have been reported in many sandstone-type uranium deposits, which have been difficult to explain in normal diagenetic environments. In the paper entitled "A linkage between uranium mineralization and high diagenetic temperature caused by coal self-ignition in the southern Yili Basin, northwestern China", Shi et al. (2020) provide evidence from optical microscopy, field-emission scanning-electron microscopy in conjunction with energy-dispersive X-ray spectrometry, X-ray powder diffraction and inductively coupled plasma mass spectrometry (ICP-MS) suggesting that self-ignition occurred when coal beds were exposed on the surface in the southern margin of the Yili Basin, resulting in the formation of "burnt rocks". They further propose that supergene uranium-bearing fluids penetrated through the warm burnt rocks, underwent chemical reactions as they progressively cooled when they traversed down through the underlying permeable sandstone beds, resulting in uranium mineralization. Whether the chemical composition of the surface water groundwater in uranium mineralized areas may be used to locate uranium deposits and/or help understand the mineralization mechanisms is an appealing topic. Thus, in the paper entitled "Hydrogeochemical characteristics of the sandstone-hosted uranium mineralization in northern Ordos Basin, China", Chen G et al. (2020) conducted analyses of waters from streams, lakes, shallow wells and boreholes from the northern part of the Ordos Basin, where a number of uranium deposits have been discovered. Their analytical results indicate that the waters are of meteoric origin, and uranium is dominantly dissolved as $UO_2(OH)^{3-}$ and $UO_2(CO3)_3^{4-}$. Furthermore, it is suggested that the current groundwater is undersaturated with uraninite and does not represent the ore-forming fluid when the uranium deposits were formed; the contours of uranium concentrations in the waters indicate that elevated uranium concentrations occur near orebodies, but not surrounding the orebodies. The efficient production of uranium through in-situ leaching requires a good understanding of the mineralogical and petrographic characteristics of the ores and wall rocks. In the paper entitled "Petrology, mineralogy, and ore leaching of sandstone-hosted uranium deposits in the Ordos Basin, North China", Liu et al. (2020) conducted studies of the ore-bearing sandstones from the northern part of the Ordos Basin, which show that the uranium minerals (coffinite, pitchblende, and brannerite) are closely associated with pyrite and mainly occur in sandstones rich in organic matter. Based on these observations and experimental tests, they suggest that the classical *in-situ* leaching technique with $H_2SO_4 + H_2O_2$ solutions is inefficient due to precipitation of carbonate cement block porosities, and that the $CO_2 + O_2$ *in-situ* leaching technology has been demonstrated to be more efficient.

The two papers on volcanic-related uranium deposits are both on the Xiangshan Volcanic Basin, which represents the most important volcanic-related uranium ore district in China. Guo et al. (2020), in the paper entitled "Key factors controlling volcanic-related uranium mineralization in the Xiangshan Basin, Jiangxi Province, South China: A review", summarized the results of previous studies on the uranium deposits as well as the local and regional geology of the Xiangshan Basin, including host rocks, ore-controlling structures, alterations, mineralization, fluid inclusions, and geochronological and geochemical data of the uranium deposits. Based on the review of these previous studies, they propose a comprehensive genetic model in which the uranium mineralization took place 10–65 Ma after the formation of the host volcanic rocks, and was coeval with the development of the red bed basins and mafic magmatism. It is proposed that oxidizing basinal fluids circulated into the volcanic basin along brittle structures and extracted uranium from the volcanic rocks, with fluid flow facilitated by heat related to the mafic magmatic activities. Deng et al. (2020), in the paper entitled "Ore-controlling structures of the Xiangshan volcanic Basin, SE China: Revealed from three-dimensional inversion of Magnetotelluric data", focused on the study of ore-controlling structures in the Xiangshan Basin using the high-resolution three-dimensional (3D) Magnetotelluric (MT) method. The faults identified with this method correspond well with the ore-controlling NE- and NS-trending faults observed on the surface. It is inferred that these fault zones played the role of conduits for both the descending meteoric water and upwelling fluids derived from depth.

Granite-related uranium deposits are best developed in South China, where voluminous granitic intrusions, especially those of Mesozoic ages, are widely distributed. In the paper entitled "Comparison of granite-related uranium deposits in the Beaverlodge district (Canada) and South China – a common control of mineralization by coupled shallow and deep-seated geologic processes in an extensional setting", Chi et al. (2020) reviewed the geological, geochronological and geochemical characteristics of granite-related uranium deposits in South China and compared them with the so-called "vein-type" uranium deposits in the Proterozoic Beaverlodge district in Canada, most of which are also spatially related to granitic intrusions. It was noticed that despite their great difference in age, the granite-related uranium deposits in South China and Beaverlodge share many similarities, especially the timing of mineralization significantly postdating the host granites, and *syn*-mineralization development of red bed basins with accompanying coeval mafic magmatism in extensional tectonic settings. It is proposed that the coupling of shallow (red bed basin and oxidizing basinal fluid development) and deep-seated (mantle-derived magmatism and related thermal activity) processes played a critical role in the formation of the granite-related uranium deposits. Wang et al. (2020a), Wang et al. (2020b), in the paper entitled "Provenances of the Ediacaran sedimentary rocks in the Zhuguangshan area and their implications for granitoid-related uranium mineralization in South China", conducted geochronological and geochemical studies of the Neoproterozoic terrigenous clastic sedimentary rocks in the Zhuguangshan area, where Mesozoic granite-related uranium deposits are well developed, with an aim to understand why this area is particularly favorable for uranium mineralization. It was found that the terrigenous clastic sedimentary rocks were derived from recycled sedimentary sources that underwent mild to intensive chemical weathering, resulting in high maturity and high U and Th contents, which provide the basis to form uranium fertile granites and eventually uranium deposits.

In the category of intrusive-type uranium deposits, representative examples have also been extensively found in the Qinling Orogenic Belt situated between the North China and South China cratons. Chen Y et al. (2019), in the paper entitled "Genesis of the Guangshigou pegmatite-type uranium deposit in the North Qinling Orogenic Belt, China", presented systematic zircon U–Pb ages, Lu–Hf isotopic data, and mineral chemistry of uranium-rich biotite pegmatite dikes related to the Guangshigou uranium deposit in the North Qinling Orogenic Belt. Their results suggest that the uranium mineralization took place in Silurian, in association with pegmatite dikes that were derived from low-degree partial melting of the Proterozoic Qinling Group. The uranium mineralization is related to both magma assimilation and fractional crystallization. Another intrusive-type uranium deposit, the Huayangchuan U-Nb-Pb polymetallic deposit, was studied by Cai et al. (2020) in the paper entitled "Multiple episodes of tectono-thermal disturbances in the Huayangchuan U-Nb- Pb polymetallic deposit in the Xiaoqinling region, central China and their significances on metallogeny". The deposit consists of a series of carbonatite veins or dikes and to a less extent pegmatite dikes hosted in a suite of Neoarchean to Paleoproterozoic gneisses. Structural analyses revealed six phases of deformation and biotite $^{40}Ar/^{39}Ar$ dating suggests multiple thermal events from Late Triassic to early Cenozoic. A two-stage mineralization model is proposed, with an early phase of ore veining in the Late Triassic to latest Jurassic during the nearly N-S collision between the South and North China blocks, and a late phase of ore veining or reworking in the Early Cretaceous related to the Yanshanian (late Mesozoic) orogeny.

Li et al. (2019), in the paper entitled "Black and red alterations associated with the Baimadong uranium deposit (Guizhou, China): geological and geochemical characteristics and genetic relationship with uranium mineralization", presented geological and geochemical data of the Baimadong uranium deposit in southwestern China and discussed its genesis. This carbonate-hosted uranium deposit was generally assigned to the "carbonaceous-siliceous-pelitic rock-type" uranium deposits in the Chinese literature. Based on petrographic, whole-rock geochemistry and organic geochemistry, it is proposed that the deposit was formed by U-bearing fluid flowing through a brecciated carbonate enriched in organic matter, which was previously introduced as petroleum migrated through, both controlled by the same structure. It was proposed that although the Baimadong uranium deposit is associated with black rocks which appear to resemble black shales, it is clearly different from black shale uranium deposits as defined by IAEA (2018), and it is best classified as carbonate-hosted uranium deposits.

It is known that many, but not all, IOCG deposits are enriched in uranium, and it is of both scientific and economic interest to study uranium enrichment in these deposits. A number of IOCG deposits have been found in the Kangdian region in southwestern China, and the paper by Song et al. (2020), entitled "Uranium enrichment in the Lala Cu-Fe deposit, Kangdian region, China: a new case of uranium mineralization associated with an IOCG system", represents an effort to evaluate uranium mineralization potential of these deposits. Two phases of uranium mineralization were documented in the Lala Cu-Fe deposit based on petrographic studies. The first phase is associated with the primary Cu – Fe – Mo – REE mineralization, and the second phase is characterized by remobilization of U and Mo, and to lesser extent Cu and REE, with new introduction of fluorite and carbonates. The Lala Cu-Fe deposit represents a new case of IOCG deposits with U (and REE) enrichment.

In summary, the fourteen papers in the Special Issue make a good representation of the more important types of uranium deposits in China, notably, the sandstone-hosted, volcanic-hosted, granite-hosted, and carbonate-hosted. Examples of the intrusive-type (e.g., pegmatite- and carbonatite-related) and polymetallic iron oxide breccia complex-type are also presented.

Although the uses of '-type', '-hosted', and '-related' are somewhat arbitrary in this introduction and the papers in this Special Issue, the meaning is generally unambiguous in the context. The papers in this Special Issue highlight the diversity of uranium deposits in China, as is also true globally. It is hoped that this Special Issue will not only prompt more in depth studies of uranium deposits in China and elsewhere in the world, but also stimulate the innovation of exploration technologies for multi-type energy resources.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References

Cai, J., Yu, D., Xu, D., Gao, C., Chen, G., Yu, D., Jiao, Q., Ye, T., Zou, S., Li, L., 2020. Multiple episodes of tectono-thermal disturbances in the Huayangchuan U-Nb-Pb polymetallic deposit in the Xiaoqinling region, central China and their significances on metallogeny. Ore Geol. Rev. 127 (2020), 103755.

Cai, Y.Q., Zhang, J.D., Li, Z.Y., Guo, Q.Y., Song, J.Y., Fan, H.H., Liu, W.S., Qi, F.C., Zhang, M.L., 2015. Outline of uranium resources characteristics and metallogenic regularity in China. Acta Geologica Sinica 89 (6), 1051–1069 (Chinese with English abstract).

Chen, G., Sun, Z., Nie, F., Li, C., Zhen, Y., Zhou, Z., 2020. Hydrogeochemical characteristics of the sandstone-hosted uranium mineralization in northern Ordos Basin, China. Ore Geol. Rev. 126 (103769), 1–14.

Chen, Y., Hu, R., Bi, X., Luo, J., 2019. Genesis of the Guangshigou pegmatite-type uranium deposit in the North Qinling Orogenic Belt, China. Ore Geol. Rev. 115 (103165), 1–14.

Chi, G., Ashton, K., Deng, T., Xu, D., Li, Z., Song, H., Liang, R., Kennicott, J., 2020. Comparison of granite-related uranium deposits in the Beaverlodge district (Canada) and South China – A common control of mineralization by coupled shallow and deep-seated geologic processes in an extensional setting. Ore Geol. Rev. 117 (103319), 1–17.

Cuney, M., 2009. The extreme diversity of uranium deposits. Mineralium Deposita 44, 3–9.

Deng, J., Yu, H., Chen, H., Du, Z., Yang, H., Li, H., Xie, S., Chen, X., Guo, F., 2020. Ore-controlling structures of the Xiangshan volcanic Basin, SE China: Revealed from three-dimensional inversion of magnetotelluric data. Ore Geol. Rev. 127 (103807), 1–15.

Guo, F., Li, Z., Deng, T., Qu, M., Zhou, W., Huang, Q., Shang, P., Zhang, C., Yan, Z., 2020. Key factors controlling volcanic-related uranium mineralization in the Xiangshan Basin, Jiangxi Province, South China: A review. Ore Geol. Rev. 122 (103517), 1–15.

Hu, R.Z., Bi, X.W., Zhou, M.F., 2008. Uranium metallogenesis in South China and its relationship to crustal extension during the Cretaceous to Tertiary. Econ. Geol. 103, 583–598.

Huang, S.X., Du, L.T., Xie, Y.X., Zhang, D.S., Chen, G., Wan, G.L., Ji, S.F., 1994. Uranium deposits in China. In: Song, S.H., Ed., Mineral Deposits in China, pp. 329–385.

IAEA, 2018a. Geological classification of uranium deposits and description of selected examples. IAEA-TECDOC-1842 415 p.

IAEA, 2018b. IAEA annual report 2017 www.iaea.org, GC(62)/3, 159p.

Li, Y., Zhang, C., Chi, G., Duo, J., Li, Z., Song, H., 2019. Black and red alterations associated with the Baimadong uranium deposit (Guizhou, China): Geological and geochemical characteristics and genetic relationships with uranium mineralization. Ore Geol. Rev. 111 (102981), 1–17.

Min, M., 1995. Carbonaceous-siliceous-pelitic rock type uranium deposits in Southern China: Geological setting and metallogeny. Ore Geol. Rev. 10, 51–64.

NEA and IAEA, 2018. Uranium 2018: Resources, production and demand. NEA No. 7413, 457 p.

Nie, F., Yan, Z., Feng, Z., Li, M., Xia, F., Zhang, C., Wang, Y., Yang, J., Kang, S., Shen, K., 2020. Genetic models and exploration implication of the paleochannel sandstone-type uranium deposits in the Erlian Basin, North China – A review and comparative study. Ore Geol. Rev. 127 (2020), 103821.

Shi, Z., Chen, B., Wang, Y., Hou, M., Jin, X., Song, H., Wang, X., 2020. A linkage between uranium mineralization and high diagenetic temperature caused by coal self-ignition in the southern Yili Basin, northwestern China. Ore Geol. Rev. 121 (103443), 1–14.

Song, H., Chi, G., Zhang, C., Xu, D., Xu, Z., Fang, G., Zhang, G., 2020. Uranium enrichment in the Lala Cu-Fe deposit, Kangdian region, China: A new case of uranium mineralization associated with an IOCG system. Ore Geol. Rev. 121 (103463), 1–13.

Su, X., Liu, Z., Yao, Y., Du, Z., 2020. Petrology, mineralogy, and ore leaching of sandstone-hosted uranium deposits in the Ordos Basin, North China. Ore Geol. Rev. 127 (103768), 1–11.

Wang, K., Sun, T., Yu, H., Sun, L., 2020. Provenances of the Ediacaran sedimentary rocks in the Zhuguangshan area and their implications for granitoid-related uranium mineralization in South China. Ore Geology Reviews xxx (2020), xx – xx.

Wang, S., Cheng, Y., Xu, D., Miao, P., Jin, R., Zhang, T., Xu, Z., Cheng, X., Zhao, L., Li, C., Zhang, X., 2020b. Late Cretaceous-Cenozoic tectonic-sedimentary evolution and U-enrichment in the southern Songliao Basin. Ore Geol. Rev. 126 (103786), 1–17.

Zhang, J.D., Li, Z.Y., Cai, Y.Q., Guo, Q.Y., Li, Y.L., Han, C.Q., 2012. The main advance and achievements in the potential evaluation of uranium resources in China. Uranium. Geology 28 (6), 321–326 (Chinese with English abstract).

Zhang, X., Nie, F., Su, X., Xia, F., Li, M., Yan, Z., Zhang, C., Feng, Z., 2020. Relationships between Meso-Cenozoic denudation in the Eastern Tian Shan and uranium mineralization in the Turpan-Hami basin, NW China: Constraints from apatite fission track study. Ore Geol. Rev. 127 (2020), 103820.