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Editorial

Gold deposits of China: A special issue of ore geology reviews☆

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This volume of Ore Geology Reviews is dedicated to Dr Feng-Jun Nie and credits his significant contribution to understanding the ore deposits of China. In recent years, he has dedicated his life to the study of mineralization in the North China Craton and Central Asian Orogen to the north, and that is the focus of this volume.

谨将本《矿床地质论评》专辑献给聂凤军博士，以表彰他对中国矿床地质研究所做出的杰出贡献。聂凤军博士近年来一直致力于华北克拉通及其北部中亚造山带的成矿规律研究，这也是本专辑的焦点。

China is currently positioned as the largest global producer of gold with a 2014 production of 450 t from predominantly epithermal deposits, which places it well ahead of production from other countries (Fig. 1; United States Geological Survey, 2015). Despite this strong position as a producer, China has gold reserves that are much smaller; of the 33,000 t of gold in global reserves, only 1900 t is in China (USGS, 2015). Zhang et al. (2015) report a study of the history and economics of gold mining in China, and their work reports reserve figures from Xu (2012), which are compliant with Chinese rule sets on classifications following the National codes on classification of mineral reserves and resources. There is no exact alignment of categories in the JORC and Chinese codes, so the comparisons must be treated with commensurate caution. Continued production of gold in China depends on continued exploration success, and this success is rooted in the technical excellence in discovery that is underpinned by sound geological principles and new knowledge.

Epithermal deposits are formed from meteoric hydrothermal with varying proportion of magmatic hydrothermal fluids, which are commonly driven by the magma's heat energy. Such deposits are generally formed in the Earth's crust at shallow depths with temperatures of <400° C and depths of ~2 km. Epithermal deposits have been classified as low sulfide-type, high sulfide-type and alkaline-type, alunite-kaolinite type (acidic sulfate type) and adularia-sericite type (Bonham, 1986; Heald et al., 1987; Pirajno, 2009). The tectonic setting for these epithermal gold deposits include continental-margin arcs and island-arcs, and back-arcs situated above subduction zones (e.g. Sillitoe, 2000; Hedenquist et al., 2000). They are dominantly distributed in circum-Pacific areas, Himalayas and the combined northern edge of the North China Craton (NAC) and the Central Asian Orogenic Belt (CAOB) immediately to the north of the NCC. An overview of gold mineral systems in China can be found in Pirajno (2014).

The northern edge of the NCC and the CAOB form a major gold endowed region on Earth hosting several large-scale gold deposits (Goldfarb and Santosh, 2014; Li et al., 2012a; Yang et al., 2003). Examples include Muruntau (175 Moz @ 3.5–11 g/t Au; Mao et al., 2004), Zarmitan (10 Moz @ 9.8 g/t Au; Abzalov, 2007), Kumtor (18 Moz @ 2–6 g/t Au; Mao et al., 2004), Haoyaoerhudong (148 t @ 0.62 g/t Au; Wang et al., 2014), Zhulazhaga (50 t @ 4 g/t Au; Ding et al., 2015–in this issue), and Bilihe (30 t @ 4.5 g/t Au; Qing et al., 2011). These deposits are hosted predominantly by Precambrian rocks, and are spatially and temporally associated with late Paleozoic felsic magmatism in the region (Mao et al., 2004; Abzalov, 2007; Qing et al., 2011; Wang et al., 2014; Ding et al., 2015–in this issue).

This volume of papers was designed to focus attention on the latest developments in understanding the geology of important gold deposits and gold producing areas in China with the aim to understand the regional structural, geochemical and geochronology setting for the mineralization. The papers cover a range of gold deposit types that link to a range of genetic models. The deposits are located across China and vary in contained gold reserves as shown in Fig. 2.

Bao et al. (2015–in this issue) describe the geology of the newly discovered ca. 99 Ma Gaosongshan epithermal gold deposit in the Lesser Hinggan Range of the Heilongjiang Province. The deposit is classified as an adularia-sericite epithermal deposit associated with tensional faulting and has a low-sulfide content with a high concentration of

☆ The citations in the text that relate to this special issue may be added at the stage of production of the journal issue.

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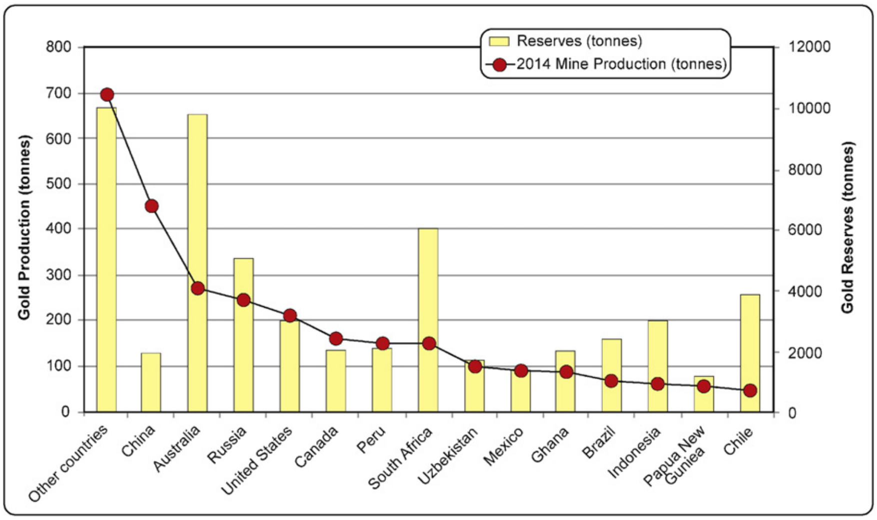

Fig. 1. Gold production and gold reserves by country. The data are sourced in USGS (2015) where metric units are used. Note that the Chinese definitions of the term "Reserve" are based on the Chinese Ministry of Lands and Resources classification scheme, and there is no direct alignment with the JORC classification system (Bucci, 2015). The authors of the papers in this volume have followed the Chinese rule-sets on reserve statements.

gold hosted by chalcedonic quartz, which makes the deposit both unique and economically important in the area.

Bao et al. (2015–in this issue) describe the geology of the Dongping gold deposit. Geochronology and isotope ratio data provide evidence for a genetic link between the formation of the deposit and two phases of hydrothermal activity. The contribution provides fluid inclusion and isotope data that support a mantle contribution to fluids from which gold mineralization was deposited.

Cai et al. (2015) report new structural data for the Baolun gold mine in Hainan Island, South China. Field mapping indicates five

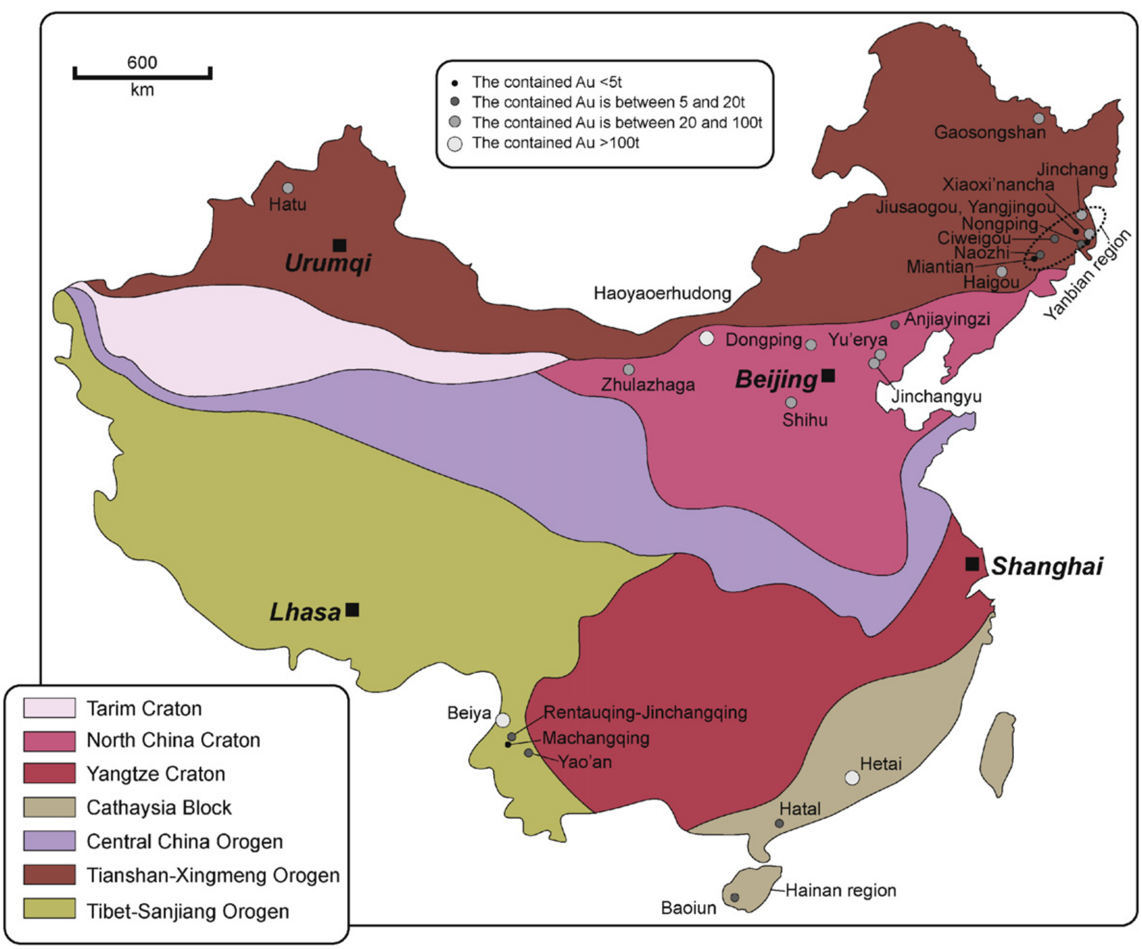

Fig. 2. Simplified geological map of China showing the location and contained gold reserves of the deposits reviewed in this volume. Modified after Ouyang et al., 2013.

phases of deformation; the mesothermal orogenic type of gold deposit was formed at an oblique dextral shear between the D1 and D3 events. Re–Os isotopic studies indicate a Late Triassic age for the mineralizing event.

Ding et al. (2015–in this issue) report a new geological description of the Zhulazhanga gold deposit located at the northern margin of the NCC They demonstrate that this epigenetic style of deposit formed in response to metal deposition from hydrothermal fluids in a shale host. Gold mineralization is controlled by extensional fractures. Hydrogen and oxygen isotope data indicate a mixed magmatic–hydrothermal source for the fluids, and there appears to be a direct spatial and temporal linkage between the deposit and a Hercynian-aged granite porphyry.

Fu et al. (2015–in this issue) describe the geology of the structurally controlled ca. 133 to 126 Ma Anjiayingzi gold deposit, which is hosted by NE-trending brittle–ductile and brittle faults in Precambrian and ca. 133 Ma granite. The mineralization is characterized by low Au/Ag ratios of <1 and high sulfide contents of 4–30 vol.%, and consists of quartz and polymetallic sulfides stage. The mineralization was deposited at 245–358°°C from a H_2O–CO_2–NaCl fluid with salinity of 1.3–15.6 wt.% NaCl equivalent and a trapping pressures of 50–110 MPa (corresponding to average depth of 2.5 km under lithostatic load or 7.5 km under hydrostatic load). The δD and $\delta^{18}O_{H2O}$ and Pb isotope values for the ore are interpreted to be associated with a mineralizing fluid originating from a concealed intrusion.

Li et al. (2015–in this issue) report new data for the Beiya gold deposit, which is located in the central part of the Jinshajiang–Honghe strike-slip belt, at the junction zone of the Tethys–Himalaya orogenic belt and the Yangtze Craton in SW China. The geological and geochemical data support a model in which alkaline porphyry stocks drive the fluid flux responsible for gold-rich polymetallic style of mineralisation at Beiya.

Liu et al. (2015–in this issue) describe the geology of the ca. 282 to 182 Ma Haoyaoerhudong gold deposit in Inner Mongolia. This contribution presents the timing of mineralization established with new geochronology and the source of the mineralizing fluids is linked to magmatic and hydrothermal processes. The deposit is hosted by metamorphosed Mesoproterozoic black shale and is associated with structurally controlled sulfide (-quartz) veins. The sulfide mineral assemblage is pyrrhotite–pyrite (–arsenopyrite–chalcopyrite–sphalerite) and associated with a weak hydrothermal alteration characterized by a silica halo with variable amounts of biotite, sericite and carbonate.

Liu et al. (2015–in this issue) report a new study of the geology of for the Yuérya gold deposit located in Hebei Province. The deposit is closely associated with a granitic magmatism and fluids produced during subduction along the southern margin of the NCC. This paper documents the alteration assemblages associated with the mineralization, and uses this information to understand the timing of formation of the gold mineralization.

Ren et al. (2015–in this issue) provide a new description of gold deposits in the Yanbian region of Jilin Province. The deposits are described and classified as orogenic intrusion-related epithermal deposits associated with quartz diorite porphyries. Their age data and observations point to two phases of deposit formation, and linkages to regional continental collision and extension events.

Shen et al. (2015–in this issue) provide evidence for two fluid sources in the formation of the Hatu gold field in the Xinjiang region. This structurally-controlled orogenic style of gold deposit was derived by hydrothermal deposition from a fluid derived largely from a crustal source, but with an identifiable mantle contribution.

Song et al. (2015) provide a new description of the Jinchangyu gold deposit close to the northeastern margin of the NCC. In the paper the authors show that the deposit is related to alkaline magmatism in a structural corridor. The paper describes the alteration geology, fluid inclusion geochemistry, and isotope ratio studies. The data indicate a late Triassic age for the mineralization, and association with granites produced by collision of the NCC with the Siberian craton.

Wang et al. (2015) describe the ca. 133 Ma Shihu gold deposit, which is hosted by the Archean Fuping Complex in the NCC. The mineralization is spatially and temporally related to numerous quartz diorite dykes. Sulfides associated with the gold have $\delta^{34}S$ values ranging from −1 to 2‰ interpreted to have a magmatic origin. The $\delta^{18}O_{fluid}$ (2.1 to 7.0‰) and $\delta^{18}D_{SMOW}$ (−93.2 to −65‰) data are interpreted to be associated with magmatic fluids mixed with meteoric–hydrothermal fluid. Lead isotopic, Sr isotope and Nd isotope data from ore are consistent with a lower crustal source with input from the mantle.

Xu et al. (2015) investigate the redox conditions responsible for the genesis of porphyry Cu–Au mineralization in the Jinshajiang–Red River alkaline magmatic belt in SW China. The intrusions and ore deposits are localized in a strike-slip crustal framework where a magmatic and hydrothermal event triggered major Cu–Au mineralization at ca. 40–30 Ma,

Zheng et al. (2015) provide a description of the fluid inclusion geochemistry of the ductile shear zone containing the Hetai goldfield in South China. The authors propose that this deposit is typical of orogenic gold deposits, and was formed from metamorphic fluids in a ductile shear zone.

Finally, it rests with the Guest Editors of this special volume to thank the authors for their diligent and careful work, and for their patience with the review process. The papers benefited from a peer review process. The following individuals are thanked for undertaking one or more reviews of the manuscripts in this volume: Ping Shen, Leon Bagas, Sihong Jiang, Yang Song, Chris Pereira, Neng Jiang, Xueming Yang, Kay Thorne, Qingdong Zeng, Xiaoming Sun, Meifu Zhou, Yifei Liu, Bo Peng, Huayong Chen, Jianfeng Gao, Olivier Pierre Kreuzer, Jianggui Sun, Yongzhang Zhou, and Yongfeng Zhu. The Guest Editors would like to thank Chunhua Liu for assistance with Fig. 2 in the Preface, and Vivian Feng for handling various questions during the editorial process.

Conflict of interest

I have no conflict of interest with respect to this Preface.

References

Abzalov, M., 2007. Zarmitan granitoid-hosted gold deposit, Tian Shan belt, Uzbekistan. Econ. Geol. 102 (3), 519–532.
Bao, Z., Li, C., Zhao, Z., 2015. Metallogeny of the syenite-related Dongping gold deposit in the northern part of the North China Craton: a review and synthesis. Ore Geol. Rev. 73 (2), 198–210 (in this issue).
Bonham, H.F., 1986. Models for volcanic hosted epithermal precious metal deposits: a review. International Volcanological Congress, Hamilton, New Zealand Proceedings, Symposium 5, pp. 13–17.
Bucci, L., 2015. JORC and the Chinese resource classification system — an SRK view. SRK News 36, 10 (http://www.na.srk.com/fr/node/2410).
Ding, C., Nie, F., Jiang, S., Liu, Y., Cao, Y., 2015. Characteristics and origin of the Zhulazhaga gold deposit in Inner Mongolia, China. Ore Geol. Rev. 73 (2), 211–221 (in this issue).
Fu, L., Wei, J., Chen, H., Bagas, L., Tan, J., Li, H., Zhang, D., Tian, N., 2015. The relationship between gold mineralization, exhumation of metamorphic core complex and magma cooling: formation of the Anjiayingzi Au deposit, northern North China Craton. Ore Geol. Rev. 73 (2), 222–240 (in this issue).
Goldfarb, R.J., Santosh, M., 2014. The dilemma of the Jiaodong gold deposits: are they unique? Geosci. Front. 5, 139–153.
Heald, P., Foley, N.K., Hayba, D.O., 1987. Comparative anatomy of volcanic hosted epithermal deposits: acid sulfate and adularia sericite types. Econ. Geol. 82, 12–26.
Hedenquist, J.W., Arribas, R.A., Gonzalez, U.E., 2000. Exploration for epithermal gold deposits. Rev. Econ. Geol. 13, 245–277.
Li, J.W., Bi, S.J., Selby, D., Chen, L., Vasconcelos, P., Thiede, D., Zhou, M.F., Zhao, X.F., Li, Z.K., Qiu, H.N., 2012. Giant Mesozoic gold provinces related to the destruction of the North China craton. Earth Planet. Sci. Lett. 349–350, 26–37.
Li, W.-C., Wang, J.-H., He, Z.-H., Dou, S., 2015. Formation of Au-polymetallic ore deposits in alkaline porphyries at Beiya, Yunnan, Southwest China. Ore Geol. Rev. 73 (2), 241–252 (in this issue).
Liu, C., Nie, F., Bagas, L., 2015. Geology and ore genesis of the Yu'erya gold deposit, eastern Hebei Province, China. Ore Geol. Rev. 73 (2), 270–283 (in this issue).
Mao, J.W., Konopelko, D., Seltmann, R., Lehmann, B., Chen, W., Wang, Y.T., Eklund, O., Usubaliev, T., 2004. Postcollisional age of the Kumtor gold deposit and timing of Hercynian events in the Tien Shan, Kyrgyzstan. Econ. Geol. 99 (8), 1771–1780.
Ouyang, H.G., Mao, J.W., Santosh, M., Zhou, J., Zhou, Z.H., Wu, Y., Hou, L., 2013. Geodynamic setting of Mesozoic magmatism in NE China and surrounding regions: perspectives from spatio-temporal distribution patterns of ore deposits. J. Asian Earth Sci. 78, 222–236.

Pirajno, F., 2009. Hydrothermal Processes and Mineral Systems. Springer (1250 pp.).

Pirajno, F., 2014. Gold in China. Gold14@Kalgoorlie, International Symposium, Australian Institute of Geoscientists, Bulletin 59, pp. 104–106.

Qing, M., Ge, L.S., Tang, M.G., Qu, W.J., Yuan, S.S., Zhao, Y.S., 2011. Molybdenite Re–Os isotope age of Bilihe large-size porphyry gold deposit in Sunid Right Banner of Inner Mongolia and its geological significance. Mineral Deposits 30 (1), 11–20 (in Chinese with English abstract).

Ren, Y.-S., Chen, C., Zou, X.-T., Zhao, X.-T., Hao, Y.-J., Hou, H.-N., Hu, Z.-C., Jiang, G.-H., 2015. The age, geological setting, and types of gold deposits in the Yanbian and adjacent areas, NE China. Ore Geol. Rev. 73 (2), 284–297 (in this issue).

Shen, P., Pan, H., Zhu, H., 2015. Two fluid sources and genetic implications for the Hatu gold deposit, Xinjiang, China. Ore Geol. Rev. 73 (2), 298–312 (in this issue).

Sillitoe, R.H., 2000. Gold-rich porphyry deposits: descriptive and genetic models and their role in exploration and discovery. Rev. Econ. Geol. 13, 315–345.

USGS, 2015. Mineral commodity summary. Gold. http://minerals.usgs.gov/minerals/pubs/commodity/gold/mcs-2015-gold.pdf.

Wang, J.P., Liu, J.J., Peng, R.M., Liu, Z.J., Zhao, B.S., Li, Z., Wang, Y.F., Liu, C.H., 2014. Gold mineralization in Proterozoic black shales: example from the Haoyaoerhudong gold deposit, northern margin of the North China Craton. Ore Geol. Rev. 63, 150–159.

Wang, S., Hu, J., Song, Y., Wang, Y., Cai, X., 2015. Stable isotopic geochemical and geochronological constraints on the formation of the Shihu gold deposit: the intracontinental metallogeny of the Taihang Mountain range, eastern China.

Xu, G.Y., 2012. Strategic Research of China Gold Industry Organization and Development. Economic Management Press, Beijing, pp. 200–207 (in Chinese).

Yang, J.H., Wu, F.Y., Wilde, S.A., 2003. A review of the geodynamic 945 setting of large-scale Late Mesozoic gold mineralization in the North China Craton: an association with lithospheric thinning. Ore Geol. Rev. 23, 125–152.

Zhang, R., Pian, H.Y., Santosh, M., Zhang, S.T., 2015. The History and Economics of Gold Mining in China. Ore Geol. Rev. 65 (3), 718–727.