International Geology Review, 2015
Vol. 57, Nos. 9–10, iii–vi, http://dx.doi.org/10.1080/00206814.2015.1029543

PREFACE

Subduction and ore deposits

Subduction is fundamental to plate tectonics, consuming old oceanic crust while new oceanic crust forms at mid-ocean ridges. Subduction transports materials from the surface of the Earth into the mantle, fractionates elements during dehydration and metasomatism, and forms arc magmas and a variety of ore deposits. The deep magmagentic and metallogenic processes involved have been conceptualized as the Subduction Factory (Hacker *et al*. 2003; Sun 2003; van Keken *et al*. 2009, 2011; Sun *et al*. 2014). This special issue of *International Geology Review* on 'Subduction and ore deposits' includes 12 papers on topics including metamorphism and element fractionations (Guo *et al*. 2015; Huang and Xiao 2015), magmatism (Ding *et al*. 2015; Wang *et al*. 2015; Wu *et al*. 2015b, 2015d) and geochemistry of mafic-ultramafic rocks (Liu *et al*. 2015; Wu *et al*. 2015c), and subduction-related ore deposits (Chai *et al*. 2015; Li and Jiang 2015; Li *et al*. 2015; Wu *et al*. 2015a) (Figure 1). These studies take advantage of the excellent opportunities provided in China to study the products of ancient subduction zones.

Metamorphism is the fundamental physicochemical process occurring during plate subduction. Dehydration and metamorphism of subducting oceanic crust and sediments cause major fractionations of mobile and even immobile elements (Pearce and Peate 1995; Spandler *et al*. 2003; Xiao *et al*. 2006; Ding *et al*. 2009). High-grade metamorphic rocks of the Dabie–Sulu orogen in eastern China provide excellent opportunities to do this. A detailed study on mineral zonation patterns and mineral compositions of the Dabie vein-hosting eclogites has led to the establishment of six stages of metamorphic evolution, and four stages of fluid activities have been established. The study results indicate that the subducting South China continental crust underwent sluggish exhumation during transition from ultra-high-pressure to high-pressure conditions. Ultra-high-pressure fluid–eclogite interaction formed patchy zones in epidote eclogite and small-scale transfer of Sr, Pb, Ba, Th, and LREEs from epidote into the UHP fluid phase (Guo *et al*. 2015).

Interaction of fluids with metamorphic rocks is another hot topic related to plate subduction (Zheng *et al*. 2003, 2011; Spandler and Hermann 2006; Spandler *et al*. 2011; Ding *et al*. 2013; Cole *et al*. 2014; Cruz-Uribe *et al*. 2014). Geochemical studies on samples collected along a profile across the boundary between felsic and mafic rocks from the Dabie orogen show that retrograded eclogite has higher concentrations of K, Al, LILEs, REEs, HFSEs, Th, and U, and slightly lower concentrations of SiO_2, MgO, and CaO contents approaching the contact zone. These disparities were attributed to metasomatism by supercritical liquids generated at pressure higher than the second critical end-point in the granitic gneiss–H_2O system. This interpretation is supported by multiphase solid inclusions of amphibole ± paragonite ± clinozoisite ± quartz ± K-feldspar ± calcite ± garnet ± rutile ± zircon ± apatite within garnet in the retrograded eclogite at the contact (Huang and Xiao 2015).

Among convergent margin magmatic rocks, adakite gets special attention because of its genetic relationship to porphyry Cu–Au deposits (Thieblemont *et al*. 1997; Mungall 2002; Sun *et al*. 2011). In this special issue, three papers studied adakite (Wang *et al*. 2015; Wu *et al*. 2015b, 2015d). Adakites in the Dachagou area in the northern Lhasa terrane of Tibet were attributed to slab break-off during the southward subduction of the Bangong–Nujiang Ocean plate (a branch of the Tethys) during the Mesozoic (Wu *et al*. 2015d). Subduction may also cause intraplate magmatism through plate interaction. In the Mesozoic, continual plate interactions between the South China Block and the North China Block, the Indochina Block, and the Palaeo-Pacific plate formed some small granites in the South China Block. The Weishan pluton, one of the largest Mesozoic composite granitic complexes in Hunan Province, South China, experienced such a complex tectonic history. New study shows that the Weishan granites were generated from a single long-standing magma source by multiple magma processes, likely in response to continuous tectonothermal events during Middle Triassic to Early Jurassic time due to the interactions of four major plates (Ding *et al*. 2015).

Subduction is a favourable process for forming ore deposits (Giggenbach 1992; Kesler 1997; Sillitoe 1997, 2010; Sun *et al*. 2004; Cooke *et al*. 2005; Wilkinson and Kesler 2007; Chiaradia *et al*. 2012). The late Carboniferous Chagangnuoer ferrobasalts were attributed to partial melting of a spinel peridotite mantle source which had been modified by subduction-related fluids. In addition, incorporation of recycled Fe–Mn nodules into the source played an important role in forming Fe and Mn enrichments in the ferrobasalts (Li *et al*. 2015).

Figure 1. Locations of the studied areas in this special issue, associated with the Pacific subduction zone, the Central Asian Orogenic Belt, Qinling–Dabie orogenic belt, and the Himalaya–Tethys orogenic belt.

Zijinshan is a large epithermal–porphyry Cu–Mo–Au deposit in southeastern China. Geochemical studies on the Luoboling porphyry Cu–Mo deposit suggest that it is related to lithospheric mantle, which was metasomatized by subduction released fluids (Li and Jiang 2015).

Epithermal and porphyry Cu–Au deposits in the Yanbian area are associated with two stages of intermediate–acid magmatism (116–118 and 112–109 Ma). High-sulphidation epithermal gold deposits formed between 108 and 106 Ma, whereas gold-rich porphyry copper deposits formed between 111 and 109 Ma. Both types of deposits are associated with adakite-like intermediate–acid magmas. Magma mixing and the subduction of the Pacific plate were assigned as the main controlling factors for these deposits (Chai *et al*. 2015).

A detailed geochemical study has been carried out on the Yandong porphyry Cu deposit in the Central Asian Orogenic Belt of Northwest China. Based on major elements, trace elements, and isotopes, it was suggested that the Palaeo-Tianshan oceanic crust subducted northward beneath the Dananhu–Tousuquan arc during the early Carboniferous, and that the Yandong magma and metals were produced by partial melting of the subducted Palaeo-Tianshan oceanic slab (Wang *et al*. 2015).

In an attempt to better understand how deeply subducted crust is obducted during continental collision and its relevance to the Mesozoic tectonic history of the southeastern margin of the North China Craton, Wu *et al*. (2015a) investigated three types of xenoliths in lamprophyre dikes emplaced within a granitic body. Based on detailed zircon U–Pb dating and whole-rock geochemical data, the authors demonstrated that the banded biotite granitic gneiss xenoliths were derived from the South China Craton and represent the protolith of the granite (Wu *et al*. 2015c).

Weidong Sun
Key Laboratory of Mineralogy and Metallogeny, Guangzhou Institute of Geochemistry, Chinese Academy of Sciences, Guangzhou, China
CAS Centre for Excellence in Tibetan Plateau Earth Sciences, Chinese Academy of Sciences, Beijing, China

Xing Ding
CAS Centre for Excellence in Tibetan Plateau Earth

Sciences, Chinese Academy of Sciences, Beijing, China
State Key Laboratory of Isotope Geochemistry, Guangzhou Institute of Geochemistry, Chinese Academy of Sciences, Guangzhou, China

Ming-Xing Ling
CAS Centre for Excellence in Tibetan Plateau Earth Sciences, Chinese Academy of Sciences, Beijing, China
State Key Laboratory of Isotope Geochemistry, Guangzhou Institute of Geochemistry, Chinese Academy of Sciences, Guangzhou, China

Robert E. Zartman
Key Laboratory of Mineralogy and Metallogeny, Guangzhou Institute of Geochemistry, Chinese Academy of Sciences, Guangzhou, China

Xiao-Yong Yang
School of Earth and Space Sciences, University of Science and Technology of China, Hefei, China

References

Chai, P., Sun, J.-G., Xing, S.-W., Men, L.-J., and Han, J.-L., 2015, Early Cretaceous arc magmatism and high-sulphidation epithermal, porphyry Cu–Au mineralization in Yanbian area, Northeast China: the Duhuangling example: International Geology Review, v. 57, p. 1267–1293. doi:10.1080/00206814.2014.960013.

Chiaradia, M., Ulianov, A., Kouzmanov, K., and Beate, B., 2012, Why large porphyry Cu deposits like high Sr/Y magmas?: Scientific Reports, v. 2. doi:10.1038/srep00685.

Cole, C.S., James, R.H., Connelly, D.P., and Hathorne, E.C., 2014, Rare earth elements as indicators of hydrothermal processes within the East Scotia subduction zone system: Geochimica et Cosmochimica Acta, v. 140, p. 20–38. doi:10.1016/j.gca.2014.05.018.

Cooke, D.R., Hollings, P., and Walsh, J.L., 2005, Giant porphyry deposits: Characteristics, distribution, and tectonic controls: Economic Geology, v. 100, p. 801–818. doi:10.2113/gsecongeo.100.5.801.

Cruz-Uribe, A.M., Feineman, M.D., Zack, T., and Barth, M., 2014, Metamorphic reaction rates at □650–800°C from diffusion of niobium in rutile: Geochimica et Cosmochimica Acta, v. 130, p. 63–77. doi:10.1016/j.gca.2013.12.015.

Ding, X., Hu, Y.H., Zhang, H., Li, C.Y., Ling, M.X., and Sun, W. D., 2013, Major Nb/Ta fractionation recorded in garnet amphibolite facies metagabbro: The Journal of Geology, v. 121, p. 255–274. doi:10.1086/669978.

Ding, X., Lundstrom, C., Huang, F., Li, J., Zhang, Z.M., Sun, X.M., Liang, J.L., and Sun, W.D., 2009, Natural and experimental constraints on formation of the continental crust based on niobium-tantalum fractionation: International Geology Review, v. 51, p. 473–501. doi:10.1080/00206810902759749.

Ding, X., Sun, W.-D., Chen, W.-F., Chen, P.-R., Sun, T., Sun, S.-J., Lin, C.-T., and Chen, F.-K., 2015, Multiple Mesozoic magma processes formed the 240–185 Ma composite Weishan pluton, South China: evidence from geochronology, geochemistry, and Sr-Nd isotopes: International Geology Review, v. 57, p. 1189–1217. doi:10.1080/00206814.2014.905997.

Giggenbach, W.F., 1992, Seg distinguished lecture - magma degassing and mineral deposition in hydrothermal systems along convergent plate boundaries: Economic Geology and the Bulletin of the Society of Economic Geologists, v. 87, p. 1927–1944.

Guo, S., Ye, K., Cheng, N., Chen, Y., Su, B., and Liu, J., 2015, Metamorphic P-T trajectory and multi-stage fluid events of vein-bearing UHP eclogites from the Dabie terrane: Insights from compositional zonations of key minerals: International Geology Review, v. 57, p. 1077–1102. doi:10.1080/00206814.2014.930719.

Hacker, B.R., Abers, G.A., and Peacock, S.M., 2003, Subduction factory - 1. Theoretical mineralogy, densities, seismic wave speeds, and H2O contents: Journal of Geophysical Research-Solid Earth, v. 108. doi:10.1029/2001JB001127.

Huang, J., and Xiao, Y., 2015, Element mobility in mafic and felsic ultrahigh-pressure metamorphic rocks from the Dabie UHP Orogen, China: insights into supercritical liquids in continental subduction zones: International Geology Review, v. 57, p. 1103–1129. doi:10.1080/00206814.2014.893213.

Kesler, S.E., 1997, Metallogenic evolution of convergent margins: selected ore deposit models: Ore Geology Reviews, v. 12, p. 153–171. doi:10.1016/S0169-1368(97)00007-3.

Li, B., and Jiang, S.-Y., 2015, A subduction-related metasomatically enriched mantle origin for the Luoboling and Zhongliao Cretaceous granitoids from South China: Implications for magma evolution and Cu–Mo mineralization: International Geology Review, v. 57, p. 1239–1266. doi:10.1080/00206814.2014.979452.

Li, N.-B., Niu, H.-C., Zhang, X.-C., Zeng, Q.-S., Shan, Q., Li, C.-Y., Yan, S., and Yang, W.-B., 2015, Age, petrogenesis and tectonic significance of the ferrobasalts in the Chagangnuoer iron deposit, western Tianshan: International Geology Review, v. 57, p. 1218–1238. doi:10.1080/00206814.2015.1004136.

Liu, J.-F., Li, C., Sun, Y., and Sun, W.-D., 2015, Melt percolation in the Songshugou ultramafic massif of the Qinling orogenic belt, Central China: International Geology Review, v. 57, p. 1326–1339. doi:10.1080/00206814.2014.990525.

Mungall, J.E., 2002, Roasting the mantle: slab melting and the genesis of major Au and Au-rich Cu deposits: Geology, v. 30, p. 915–918.

Pearce, J.A., and Peate, D.W., 1995, Tectonic implications of the composition of volcanic arc magmas: Annual Review of Earth and Planetary Sciences, v. 23, p. 251–285. doi:10.1146/annurev.ea.23.050195.001343.

Sillitoe, R.H., 1997, Characteristics and controls of the largest porphyry copper-gold and epithermal gold deposits in the circum-Pacific region: Australian Journal of Earth Sciences, v. 44, p. 373–388. doi:10.1080/08120099708728318.

Sillitoe, R.H., 2010, Porphyry copper systems: Economic Geology, v. 105, p. 3–41. doi:10.2113/gsecongeo.105.1.3.

Spandler, C., and Hermann, J., 2006, High-pressure veins in eclogite from New Caledonia and their significance for fluid migration in subduction zones: Lithos, v. 89, p. 135–153. doi:10.1016/j.lithos.2005.12.003.

Spandler, C., Hermann, J., Arculus, R., and Mavrogenes, J., 2003, Redistribution of trace elements during prograde metamorphism from lawsonite blueschist to eclogite facies; implications for deep subduction-zone processes: Contributions to Mineralogy and Petrology, v. 146, p. 205–222. doi:10.1007/s00410-003-0495-5.

Spandler, C., Pettke, T., and Rubatto, D., 2011, Internal and external fluid sources for eclogite-facies veins in the Monviso meta-ophiolite, Western Alps: implications for fluid flow in subduction zones: Journal of Petrology, v. 52, p. 1207–1236. doi:10.1093/petrology/egr025.

Sun, W.D., 2003, The subduction factory, a perspective from rhenium and trace element geochemistry of oceanic basalts and eclogites: Unpub. [Ph.D. thesis]: Australian National University, 265 p.

Sun, W.D., Arculus, R.J., Kamenetsky, V.S., and Binns, R.A., 2004, Release of gold-bearing fluids in convergent margin magmas prompted by magnetite crystallization: Nature, v. 431, p. 975–978. doi:10.1038/nature02972.

Sun, W.D., Teng, F.-Z., Niu, Y.-L., Tatsumi, Y., Yang, X.-Y., and Ling, M.-X., 2014, The subduction factory: geochemical perspectives: Geochimica et Cosmochimica Acta, v. 143, p. 1–7. doi:10.1016/j.gca.2014.06.029.

Sun, W.D., Zhang, H., Ling, M.-X., Ding, X., Chung, S.-L., Zhou, J.B., Yang, X.-Y., and Fan, W.M., 2011, The genetic association of adakites and Cu-Au ore deposits: International Geology Review, v. 53, p. 691–703. doi:10.1080/00206814.2010.507362.

Thieblemont, D., Stein, G., and Lescuyer, J.L., 1997, Epithermal and porphyry deposits: The adakite connection: Comptes Rendus de L Academie des Sciences Serie Ii Fascicule a-Sciences De La Terre et Des Planetes, v. 325, p. 103–109.

van Keken, P.E., Hacker, B.R., Syracuse, E.M., and Abers, G.A., 2011, Subduction factory: 4. depth-dependent flux of H2O from subducting slabs worldwide: Journal of Geophysical Research-Solid Earth, v. 116. doi:10.1029/2010JB007922.

van Keken, P.E., Syracuse, E.M., Hacker, B.H., Abers, G.A., Fischer, K.M., Kneller, E.A., and Spiegelman, M., 2009, Modeling the subduction factory: The ins and outs from a thermal and dynamical perspective: Geochimica et Cosmochimica Acta, v. 73, p. A1372–A1372.

Wang, Y., Xue, C., Wang, J., Peng, R., Yang, J., Zhang, F., Zhao, Z., and Zhao, Y., 2015, Petrogenesis of magmatism in the Yandong region of Eastern Tianshan, Xinjiang: Geochemical, geochronological, and Hf isotope constraints: International Geology Review, v. 57, p. 1130–1151. doi:10.1080/00206814.2014.900653.

Wilkinson, B.H., and Kesler, S.E., 2007, Tectonism and exhumation in convergent margin orogens: Insights from ore deposits: The Journal of Geology, v. 115, p. 611–627. doi:10.1086/509546.

Wu, C.-Q., Zhang, Z.-W., Zheng, C.-F., and Yao, J.-H., 2015a, Mid-Miocene (~17 Ma) quartz diorite porphyry in Ciemas, West Java, Indonesia, and its geological significance: International Geology Review, v. 57, p. 1294–1304. doi:10.1080/00206814.2014.908748.

Wu, C., Jiang, T., Liu, W., Zhang, D., and Zhou, Z., 2015b, Early Cretaceous adakitic granites and mineralization of the Yili porphyry Mo deposit in the Great Xing'an Range: implications for the geodynamic evolution of northeastern China: International Geology Review, v. 57, p. 1152–1171. doi:10.1080/00206814.2014.934746.

Wu, F., Xiao, Y., Xu, L., Santosh, M., Li, S., Huang, J., Hou, Z., and Huang, F., 2015c, Geochronology and geochemistry of felsic xenoliths in lamprophyre dikes from the southeastern margin of the North China Craton: implications for the interleaving of the Dabie–Sulu orogenic crust: International Geology Review, v. 57, p. 1305–1325. doi:10.1080/00206814.2015.1009182.

Wu, H., Li, C., Hu, P., and Li, X., 2015d, Early Cretaceous (100–105 Ma) adakitic magmatism in the Dachagou area, northern Lhasa terrane, Tibet: Implications for the Bangong–Nujiang Ocean subduction and slab break-off: International Geology Review, v. 57, p. 1172–1188. doi:10.1080/00206814.2014.886152.

Xiao, Y.L., Sun, W.D., Hoefs, J., Simon, K., Zhang, Z.M., Li, S.G., and Hofmann, A.W., 2006, Making continental crust through slab melting: constraints from niobium-tantalum fractionation in UHP metamorphic rutile: Geochimica et Cosmochimica Acta, v. 70, p. 4770–4782. doi:10.1016/j.gca.2006.07.010.

Zheng, Y.F., Wu, Y.B., and Bing, G., 2003, Zircon U-Pb dating on fluid mobility during UHP rock exhumation: Geochimica et Cosmochimica Acta, v. 67, p. A582–A582.

Zheng, Y.-F., Xia, Q.-X., Chen, R.-X., and Gao, X.-Y., 2011, Partial melting, fluid supercriticality and element mobility in ultrahigh-pressure metamorphic rocks during continental collision: Earth-Science Reviews, v. 107, p. 342–374. doi:10.1016/j.earscirev.2011.04.004.