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The Lamandau IOCG deposit, southwestern Kalimantan Island, Indonesia: Evidence for its formation from geochronology, mineralogy, and petrogenesis of igneous host rocks

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ABSTRACT

The Lamandau region of Kalimantan Island, Indonesia is located in Sandaland, in the southern part of the Kuching tectonic belt. A series of Cenozoic epithermal gold deposits and Fe–Cu–Au deposits are located in the Kuching belt. The Lamandau Fe–Cu–Au deposit is hosted by diorite porphyry. In-situ zircon U–Pb dating of the diorite porphyry shows that it formed between 82.1 ± 1.7 Ma and 78.7 ± 2.3 Ma. Geochemical data indicate a depletion of high field strength elements (HFSE) in the diorite porphyry and related basalt is similar to that of arc-related igneous rocks. The diorite porphyry and basalt were probably derived from typical arc magmas related to continental margin subduction and thus are characterized by light rare earth element (REE) enrichment and HFSE depletion. The sub-chondritic Nb/Ta ratios for the basalt in the Lamandau region indicate that the subducted Pacific slab began partial melting at depths where amphibole was the major residual phase, with some residual rutile. The basalt was derived from a depleted mantle source. The composition of apatite and zircon in the diorite porphyry indicates that the dioritic magma was produced from the subcontinental mantle after it was metasomatized by slab-derived fluids. The magma had a high oxygen fugacity, thus and therefore it was particularly conducive to the precipitation of Cu, Au and other ore-forming elements. The composition of magnetite indicates that it was of volcanic origin. The magnetite has a low REE content, and a high Cu–Au content. The deposit may be classified as an IOCG mineral system. In summary, the ore-related diorite porphyry in the Lamandau region might have formed in an extensional environment during rollback of the subducting western Pacific plate. The convergent velocity between the Philippine Sea and Eurasian plates was at a minimum during the rollback, so that the margin of East Asian began to undergo rifting with associated magmatism.

1. Introduction

Kalimantan Island in Indonesia is the largest island in Southeast Asia. The Tertiary calc-alkaline magmatic belt of central Kalimantan was mainly formed during Late Oligocene to Miocene, and is generally related to the epithermal gold deposits in the western part of central Kalimantan (Daines, 1985; Mustard, 1997; Simmons and Browne, 1990; Soeria-Atmadja et al., 1999; Thompson et al., 1994; Van Leeuwen, 1994; Van Leeuwen et al., 1990). In addition to the epithermal deposits, a series of Fe–Cu–Au deposits are located in the Kuching tectonic belt on Kalimantan Island (Ding et al., 2004; Li et al., 2006; Soeria-Atmadja et al., 1999). The epithermal gold deposits in Indonesia are mainly formed on continental crust, such as in the western Sunda–Banda and the central Kalimantan arcs; porphyry deposits in the region are formed in both island and continental arc settings, such as the Cu–Au porphyry deposit in Batu Hijau, Sumbawa (Meldrum et al., 1994; Soeria-Atmadja et al., 1999). Previous studies have mainly been concerned with the geological setting of Kalimantan Island (Hutchison, 1996; Soeria-Atmadja et al., 1999; Van Leeuwen, 1994). In this study, we focus on the Fe–Cu–Au deposits in the Lamandau region of Kalimantan, and we systematically investigate the geochronology, petrogenesis, and tectonic setting of the host diorite porphyry. We also constraint the oxygen fugacity of the magma, the mineralizing fluid source, and the mineralization mechanism by analyses of the chemical composition of zircon, apatite and magnetite.

2. Geological setting

Kalimantan Island is located along the southeastern margin of the Eurasia plate, and is a part of the western Pacific tectonic–magmatic belt. The island is bordered by the South China Sea to the north, the Philippine oceanic arc and the Philippine Sea Plate to the east, the Banda and Sunda arc systems to the south, and the Sunda shelf and

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Paleozoic and Mesozoic Malay Peninsula to the west (Fig. 1). These plates and arcs surrounding Kalimantan Island have been active from the Tertiary to the present, making this a very complex tectonic setting (Li et al., 2006; Zaw et al., 2011).

The western and central parts of Kalimantan Island are underlain by Late Cretaceous to Early Tertiary graywacke to the north, the Early Cretaceous to Late Cretaceous subduction-related Schwaner intrusion to the south, and pre-Tertiary igneous, metamorphic, and deformed sedimentary rocks to the west (William et al., 1988; Zaw et al., 2011). Intermediate to felsic magmatic activity occurred on Kalimantan Island from Late Jurassic to Early Cretaceous (Soeria-Atmadja et al., 1999). The Lamandau region is located in the southwestern part of Kalimantan Island, with diorite porphyry hosting the Lamandau Fe–Cu–Au deposit.

3. Petrography

Numerous diorite porphyry and three basalt samples were collected from the Lamandau region on Kalimantan Island. The phenocryst content of the diorite porphyry is about 40%, and grains are comprised of plagioclase, pyroxene, and hornblende (Fig. 2); the matrix is aphanitic plagioclase. The plagioclase phenocrysts are mainly labradorite and andesine, with variable grain sizes (Fig. 2A, B, C). The labradorite shows polysynthetic twins (Fig. 2A, B) and the andesine shows zonal structure (Fig. 2C). The combined content of amphibole and pyroxene phenocrysts is about 20% of the rock (Fig. 2D, E, F). The pyroxene in diorite porphyry shows polysynthetic twins (Fig. 2D) and simple twins (Fig. 2E, F). About 5% magnetite is also present in matrix of the diorite porphyry (Fig. 2D, F).

4. Analytical methods

4.1. Whole rock major and trace elements

Major and trace element (including rare earth elements [REE]) concentrations were analyzed for whole rock samples by the ALS Laboratory Group, an Australian inductively coupled plasma-mass spectrometry (ICP-MS) analytical lab in Guangzhou. Detailed analytical methods were described by Liu et al. (1996).

For major element analysis, a devolatilized or ignited sample (~0.9 g) was added to lithium borate flux (~9.0 g, 50% $Li_2B_4O_7$–$LiBO_2$), mixed well and fused in an auto fluxer at a temperature between 1050 and 1100 °C, and then cooled to form a flat molten glass disk, which was then analyzed by ME-XRF-06. Analytical precisions were as follows: SiO_2: 0.8%; Al_2O_3: 0.5%; Fe_2O_3: 0.4%; MgO: 0.4%; CaO: 0.6%; Na_2O: 0.3%; K_2O: 0.4%; MnO: 0.7%; TiO_2: 0.9%; and P_2O_5: 0.8%. Analytical uncertainties were better than 1%.

Trace elements were analyzed by ICP-MS of ME-MS81. We used the $HNO_3 + HF$ seal dissolution method for trace element and REE determination by adding a Rh internal standard and converting the sample solutions into a 1% HNO_3 medium. The analytical precision for trace elements was as follows: Ba: 2.7%; Ta: 2.1%; Nb: 1.6%; Zr: 2.2%; Hf: 2.1%; Th: 2.1%; U: 3.4%; Pb: 3.2%; Ga: 1.9%; Cr: 5.3%; Co: 0.8%; Ni: 11%; Cu: 3.5%; Rb: 2.1%; Sr: 1.7%; Sc: 4.2%; V: 3.2%; and Zn: 3.0%.

The REE were analyzed by cation exchange separation-inductively coupled plasma atomic emission spectrometry (ICP-AES) with analytical precision as follows: La: 4.7%; Ce: 5.2%; Pr: 1.8%; Sm: 4.7%; Eu: 1.2%; Gd: 1.4%; Tb: 3.2%; Dy: 4.3%; Ho: 2.4%; Er: 3.9%; Tm: 4.8%; Yb: 4.3%; Lu: 3.9%; and Y: 1.8%.

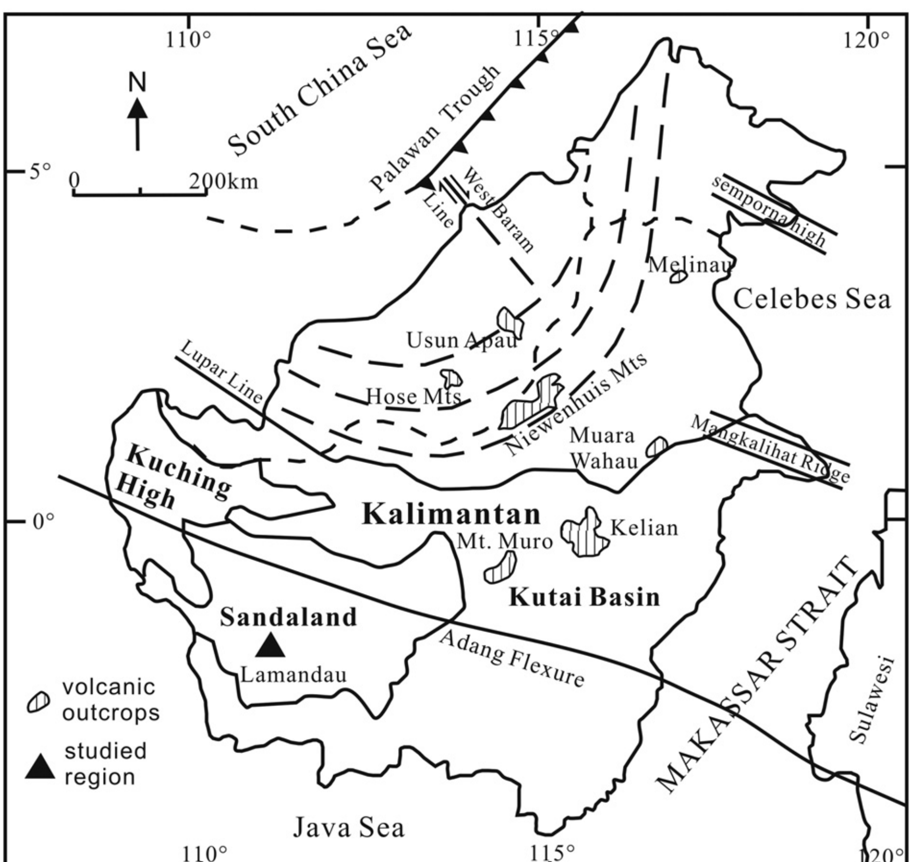

Fig. 1. Distribution of volcanic outcrops in Kalimantan.
Modified after Soeria-Atmadja et al. (1999).