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Migration of Trace Elements in Pyrite From Orogenic Gold Deposits: Evidence From LA-ICP-MS Analyses

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1 Introduction

Pyrite is the most abundant sulfide mineral in the majority of orogenic sulfide ore deposits and gold deposits. Original textures of such deposits are difficult to determine because they are lost or replaced during metamorphism or hydrothermalism. Pyrite is a very refractory mineral, it means pyrite could be an ideal mineral to preserve evidence of evolution history of the deposits.

Wet chemical analyses studies to determine trace constituents have provided much information about pyrite composition. However, several limitations must be taken into consideration. For example, it's difficult to produce pure separates, and difficult to separate grains of different crystal habits.

Electron microprobe is the most widely used in-situ microanalytical tool, but limited by relatively high detection limit (~>100ppm). The measurement of trace elements by laser ablation inductivity coupled plasma mass spectrometry(LA-ICP-MS) has advantages of in-situ, realtime, high resolution(5-10μm) and low detection limit (<1ppm) over these traditional methods. However, development of analysis of trace metal elements in sulfide minerals by LA-ICP-MS has been hampered by lack of reference materials of sulfides. In recent years large amount of work have been carried out at the CODES LA-ICP-MS analytical facility University, Australia, since they developed the calibration standard STDGL2b2 which improves the accuracy of measurement for sulphide by LA-ICP-MS.

2 Occurrence of Trace Elements

The occurrence of trace elements in pyrite can be either inclusions or substitutions. Elements mainly occur as mineral inclusions include Cu, Pb, Zn, and Ag, and elements that most likely to substitute the lattice include Co, Ni, As, Se and Te(Huston *et al*., 1995).

Analyses on trace elements in pyrite are more likely to concern about those substitute the lattice, because the quantities and ratios of nickel, cobalt, tellurium and selenium could indicate the genesis environment of ore deposits (Craig *et al*., 1998). If the levels of elements in LA-ICP-MS counts output for pyrite analysis remain more or less constant, it indicates elements may occur as substitutions in the lattice, while arrows highlight the elements are erratic, it is suspected that discrete mineral inclusions were hit by the laser beam.

In orogenic gold deposits, the invisible gold may occur as nanoparticles or substitutions, both of them could not be detected by optical or scanning electron microscopy. Since they are too small(<100nm), LA-ICP-MS is also not powerful enough to distinguish nanoparticles and lattice-bound, current LA-ICP-MS system can only differentiate Au inclusions as small as 200nm from dissolved Au. But it could be solved by correlation trends between elements, a positive correlation with Co, Ni indicates Au occurs as lattice-bound gold, while a positive correlation with Te, Ag indicates nanoinclusions.

3 Migration of Trace Elements

Theories on orogenic gold deposits show that two stages at least should have been experienced for sediment-hosted orogenic deposits: an early synsedimentary stage, and a later metamorphic or hydrothermal stage. Pyrite may initially crystallized from fifty nanometers to a few centimeters which depends on temperatures and pressures, a rapid deposition often bring in a variety of trace elements, such as Co, Ni, Se, Te, Cu, Pb, and Au. Later pyrites, which may have experienced metamorphism or hydrothermalism, are inclined to be less enriched in trace

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elements, since higher temperature lead to recrystallization or over growth earlier pyrite.

In recent year, large amount of studies about orogenic gold deposits have been focused on the source of Au and the time of gold deposits formed. Typical theories are more likely to support the view that gold is introduced from a deeply sourced fluid during the orogenic events. But according to the research for several orogenic gold deposits by Large *et al*.(2009) using a LA-ICP-MS technique, evidence showed that gold had been introduced in pyrite during early deposition and acted as invisible gold, companied by many other trace elements. During metamorphism or hydrothermalism, Pb, Zn, Cu, Ag, which often occur as inclusions in pyrite, are cleaned out and much lower than early diagenetic pyrite, invisible gold was released during this process to form free gold and gold tellurite inclusions in later pyrite generation.

The in-situ technique LA-ICP-MS has been proved to be a powerful tool to analyses the concentration and distribution of trace elements in pyrite and the evolution of a orogenic gold deposit. Six orogenic gold deposits in Western Australia have been analysed by Morey *et al*. (2008) utilizing LA-ICP-MS, the results show that visible gold formation is associated with hydrothermal alteration, invisible gold was remobilized from early-formed pyrite to form visible gold during development of rims formed by metamorphism or hydrothermalism.

4 Expectations

A number of studies have been focused on how to confirm the orogenic events really influenced the migration of trace elements in ore deposits. This problem could be well resolved by the combination of electron backscatter diffraction (EBSD), which may reveal the pyrite deformation and recrystallization history(Barrie *et al*, 2011), and LA-ICP-MS. These newly developed in-situ developed microanalytical techniques may play an important role in ore deposits research.

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