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New geochronological results and structural evolution of the Pataz gold mining district: Implications for the timing and origin of the batholith-hosted veins

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ABSTRACT

The Paleozoic Pataz–Parcoy gold mining area is located in a right-stepping jog on the regional Cordillera Blanca fault, in northern Peru. Most of the 8 million ounces of gold production from this area has come from quartz–carbonate–sulfide veins hosted by the Pataz batholith. Despite a subduction zone setting since at least the Cambrian, the area records several periods of extension and its present structure is that of a rift and graben terrain. The Pataz district (the northern part of the Pataz–Parcoy area) is dominated structurally by northwest to north northwest-striking (NW–NNW) faults and northeast to east northeast-striking (NE–ENE) lineaments, both of which have been active periodically since at least the Mississippian (Early Carboniferous). NW–NNW faults control the margins of a central horst that exposes basement schist and the Pataz batholith, and step across NE–ENE lineaments. The Lavasen graben, to the east of the central horst, contains the Lavasen Volcanics, and the Chagual graben, to the west, contains an allochthonous sedimentary sequence derived from the Western Andean Cordillera.

New SHRIMP zircon geochronological data indicate emplacement of the Pataz batholith during the Middle Mississippian, at around 338–336 Ma, approximately 10 Ma earlier than previous estimates based on $^{40}Ar/^{39}Ar$ geochronology. The calc-alkaline, I-type batholith comprises diorite and granodiorite, the latter being the major component of the batholith, and was emplaced as a sill complex within the moderately NE-dipping sequence of the Eastern Andean Cordillera. Moderate- to high-temperature ductile deformation took place on the batholith contacts during or shortly after emplacement. Following emplacement of the batholith, differential uplift occurred along NW–NNW faults forming the Lavasen graben, into which the Lavasen Volcanics were deposited. SHRIMP U–Pb in zircon ages for the Lavasen Volcanics and the Esperanza subvolcanic complex, which was intruded into the western margin of the graben, are within error of one another at ca 334 Ma. The ductile batholith contacts were cut by renewed movement on NW–NNW faults such that the margins of the batholith are now controlled by these steep brittle-ductile faults. The NW–NNW faults were oriented normal to the principal axis of regional shortening (ENE–WSW) during formation of the batholith-hosted, gold-bearing quartz–carbonate–sulfide veins. The misoriented faults were unable to accommodate significant displacement, leading to high fluid pressures, vertical extension in the competent batholith and formation of gold-bearing veins. Brittle failure of the batholith was most extensive in the northern Pataz district where the fault-controlled western contact of the batholith is offset by a swarm of NE–ENE lineaments.

The timing of vein formation is not established, despite published $^{40}Ar/^{39}Ar$ ages of 312 to 314 Ma for metasomatic white mica, which are interpreted as minimum ages of formation. Gold-bearing veins formed during or shortly after uplift of the Pataz batholith and formation of the Lavasen graben; they were therefore broadly coeval with deposition of the Lavasen Volcanics and emplacement of the Esperanza subvolcanic complex. These K-rich, weakly alkalic, ferroan (A-type) magmas may provide a viable source for the ore fluid that deposited gold in the Pataz batholith.

1. Introduction

The Pataz–Parcoy area extends north northwest over 160 km in the mainly Paleozoic Eastern Andean Cordillera of northern Peru, to include the major gold-mining districts of Pataz and Parcoy (Fig. 1). The Pataz–Parcoy area has produced more than 8 million ounces of gold (unpublished data from Compania Minera Poderosa S. A.), most of which has come from quartz–carbonate–sulfide veins in the mainly granodioritic Pataz batholith. Haeberlin et al. (2002) proposed that the Pataz–Parcoy area is part of an orogenic gold belt that extends from northern Peru to central Argentina, and lies on the

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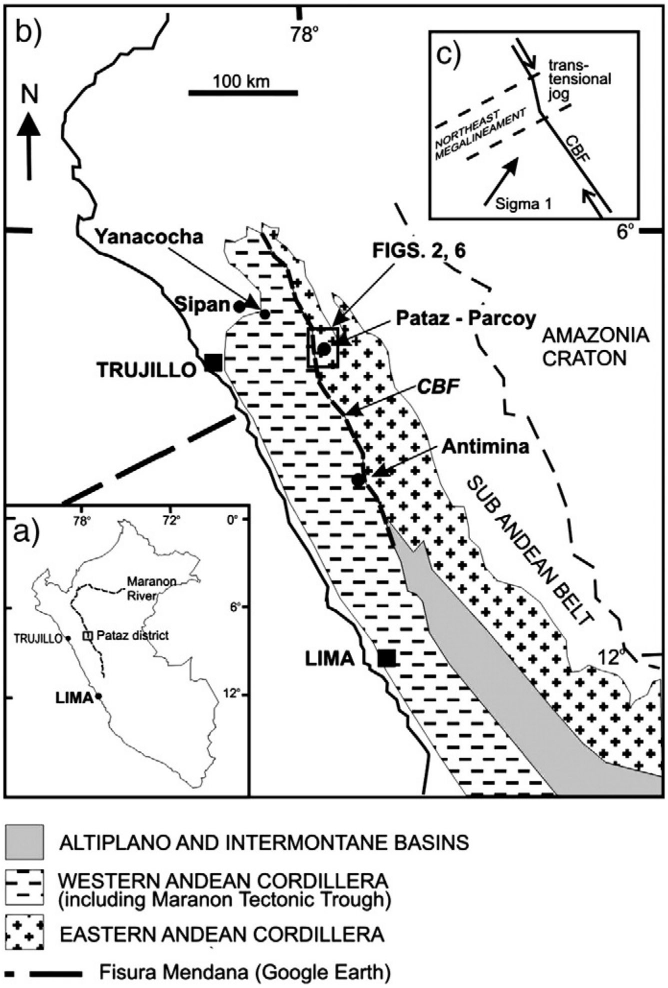

Fig. 1. Regional geological setting of the Pataz–Parcoy area. CBF: Cordillera Blanca fault. a) Location map of Peru. b) Regional geological map of northwestern Peru showing location of Pataz–Parcoy gold mining area. c) Schematic diagram illustrating proposed dextral jog on the CBF in the Pataz–Parcoy area, which was transtensional during the Mississippian.

continental side of the porphyry and epithermal deposits of the Western Andean Cordillera. Pataz, and other Devonian to Carboniferous gold districts of the Paleozoic orogenic belt (such as Ananea, Santo Domingo, Yani–Acupata, Amayapampa, Sierra de la Rinconada and Sierras de Cordoba) form the South American segment of a trans-global orogenic gold belt that circumscribed the Gondwana craton and includes well known gold mining districts in the Bendigo–Ballarat area and Charters Towers in eastern Australia (Goldfarb et al., 2001, 2005; Haeberlin et al., 2002). During the Neoproterozoic to early Paleozoic, the north Peruvian section of the Gondwana coast was a zone of subduction and accretion. It formed part of the Terra Australis orogen, which extended along the Pacific coast of Gondwana (Cawood, 2005; Chew et al., 2007).

The geology of the Pataz–Parcoy area was mapped and described by Schreiber et al. (1990a). The present paper describes in more detail the geology and tectonic evolution of the Pataz district, which forms the northern half of the Pataz–Parcoy area. The descriptions are based on results of new geological mapping in the Pataz district at a scale of 1:25,000, and six new SHRIMP U–Pb in zircon dates. The new map includes a portion of the poorly documented Lavasen Volcanics, at Misquichilca in the northeast of the Pataz district. The results are used to construct a geological history of the Pataz district, with implications for the origin of the batholith-hosted gold deposits.

2. Regional setting and geology of the Pataz–Parcoy area

Pataz and Parcoy lie within the Maranon River valley, which mimics an important NNW-striking morphologic and tectonic lineament (the Cordillera Blanca fault system of Petford and Atherton, 1992) in northern Peru, separating the Western and Eastern Andean Cordilleras (Fig. 1; Benavides-Caceres, 1999; Megard, 1984; Schreiber et al., 1990b). Regional topographic maps show that the Maranon River follows a north northwest trend for 400 km, approximately parallel to the ancient continental margin. However, in the Pataz–Parcoy area, the Maranon River flows approximately north–south, suggesting the presence of a fault bend or jog in this area (Fig. 1). It is notable that the southern limit of continental crust below the Andean Cordillera is at broadly the same latitude as Pataz (De Haller et al., 2006), suggesting the presence of an arc-normal (ENE-striking) structure in this area. Similar arc-normal structures cause segmentation along the length of the Andean Cordillera, in some cases with important metallogenic implications (Behn et al., 2001; Sillitoe, 1974). The fault bend in the Pataz–Parcoy area may have been caused by the intersection of the Cordillera Blanca fault with one of these arc-normal structures. The present day geology of the Pataz–Parcoy area is essentially a horst and graben terrane characterized by prominent northwest- to north northwest-striking (NW–NNW) faults and geological contacts, and northeast- to east northeast-trending (NE–ENE) structural lineaments (Fig. 2).

The oldest rocks in the Pataz–Parcoy area belong to the latest Neoproterozoic to Cambrian basement, termed the Maranon Complex (Table 1). The Maranon Complex comprises multiply deformed phyllite, micaceous and graphitic schists, metamorphosed to greenschist to lower amphibolite facies assemblages during the early to middle Cambrian Pampean orogeny (Cawood, 2005; Haeberlin et al., 2004). It is considered to be autochthonous with respect to the Gondwana margin and Mesoproterozoic detrital zircons in the Maranon Complex suggest derivation of a volcano-sedimentary protolith by erosion of the Sunsas–Rondonia–San Ignacio orogen of the southwest Amazonian craton (Chew et al., 2007). The volcanic and sedimentary succession that defines the Eastern Andean Cordillera was deposited unconformably on the Maranon basement during the late Cambrian and Ordovician (Table 1; Schreiber et al., 1990a; Haeberlin et al., 2004). These rocks form part of an early Paleozoic magmatic belt with geochemical characteristics (high large ion lithophile element/high field strength element ratios, negative Nb anomalies) indicative of a continental subduction zone setting (Chew et al., 2007; Witt et al., submitted to AJES). Together with the Maranon Complex, they were deformed and metamorphosed during the Early Ordovician Famatinian orogeny, at ca 480 Ma (Chew et al., 2007; c.f. Bahlburg and Herve, 1997).

The arc-related Pataz batholith (Schreiber et al., 1990a) is a 60 km long, dioritic to monzogranitic, composite intrusion that was emplaced subparallel to the north northwest structural grain of the Eastern Andean Cordillera (Fig. 2). Conflicting Mississippian (Early Carboniferous) emplacement ages for the dominant granodiorite component of the batholith were determined as approximately 328 Ma by $^{40}Ar/^{39}Ar$ on igneous biotite (Haeberlin et al., 2004), or 338 Ma by U–Pb in zircon methods (Schaltegger et al., 2006). Schaltegger et al. (2006) also suggested a third period of metamorphism in the Eastern Andean Cordillera during the Pennsylvanian (late Carboniferous), at about 312 Ma, based on U–Pb zircon ages of the anatectic Huacapistana granite. This

Fig. 2. Geological map of the Pataz district showing location of batholith-hosted gold mines and other gold mineralization. The blank area to the west of the geological map lies to the west of the Maranon River and has not been mapped at 1:25,000. The Maranon River marks the western boundary of the transtensional jog on the Cordillera Blanca fault, and also approximates the boundary between the Eastern Andean Cordillera and the Western Andean Cordillera.