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The Influence of Ore Deposits to the Development and Collapse of the Inca Civilisation between the 15th and the 16th Century

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Introduction

In South America, covering mostly the area of modern day Peru, the most developed sociopolitical entity of the Precolumbian Americas, started as the small city-state of Cusco. At the height of its power, the Inca Empire covered vast expanses of land from Ecuador to the North to Chile to the South, while the Andes formed its Eastern frontier. The population of the Empire at that time is estimated at around $16 \cdot 10^6$ people (Pemberton, 2011). While the economic system of the Incas did not include any concept of money and was based on mutual trade, the role of precious metals, namely silver and gold, as well as of other metals and minerals was pivotal in establishing distinct social strata and a domestic trading network. The Incas built upon an already rich pre-existing tradition of mining and metallurgy, which was assimilated from the peoples they conquered. By capitalising on mineral wealth and relatively advanced ore extraction and processing techniques, they created a civilisation which is remembered as being amongst the wealthiest in historical record. Of course, such sumptuousness was to prove the undoing of the Incas, as it drove the relentless Spanish conquest. In this research the quantification of the cumulative effect of the availability of different ores in the socioeconomic fabric of the Incas is attempted, so as to demonstrate how geology shaped the Age of Discovery.

Geological Setting and Ore Deposits of the Andean Cordillera

The Andes constitute the richest source of mineral wealth in the New World and are characterised by a rich metallurgical tradition since 700 BC (Cooke *et al.*, 2009). In terms of metallic ores, the Andes represent one of the richest orogenic belts, and are a source for many metals, such as Sb, Be, Bi, Cu, In, Mo, Pt, Re, Tr, Al, W, Zn and Sn. The Fe-Cu skarn deposits of the Andahuaylas-Yauri zone in Peru, are associated with quartz monzonite stocks and also contain native Au. At the Northern and Southern ends of the Andean belt there are a lot of copper deposits, dating from the Upper Palaeozoic to the Pleistocene. Most porphyry copper deposits are related to dacitic-granodioritic porphyry stocks (Oyarzún, 2000). Within modern day Peru – in the centre of the erstwhile Inca Empire – there are numerous Cu ± (Fe, Au, Zn) skarn deposits, Cu-Fe manto-type deposits, and widespread Cu vein deposits, which are considered to be the first exploited copper source (Oyarzún, 2000; and references therein). As far as Au deposits are concerned, there are epithermal Au-Ag veins, Au quartz veins, Au placer deposits, Au skarn deposits and Cu ± Au porphyry deposits in Ecuador and Peru (Noble & Vidal, 1996). In the Western Cordillera, in modern day Peru and Chile, there are numerous deposits of Ag, either in primary or secondary form and as inclusions of Ag-minerals in galena (Bellido & Montreuil, 1972). Tin is found in Tertiary deposits related to sub-volcanic intrusive bodies, which crosscut Palaeozoic clastic formations (Sillitoe *et al.*, 1975).

Gold and Silver in the Context of the Inca Society

The main source of gold of the Incas can be traced back to placer deposits, which were the first to be exploited by man. However, both porphyry and vein deposits are known to have been exploited. In general, the Inca Empire had abundant gold resources within its borders, both in its central part, in modern day Peru, as well as in Ecuador, Chile and Colombia (Petersen, 1970). While native gold was extracted from quartz veins, placer deposits in Peru were exploited at the valleys of Rio Chinchipe, Rio Mariñón, Rio Santiago de Montaña, Rio Aguarrica, Rio Morona and Rio Chachapoyas. It must be mentioned that a substancial percent of Incan gold ornaments where not made of pure gold. Rather, using a depletion gilding treatment (Petersen, 1970) objects made from a Cu-Au-Ag alloy were given an even superficial golden layer. Interestingly, due to the importance of gold and silver extraction, and for purposes of production intensification the Inca employed the mit'a labour system, using *«mitmaqkunas»* – the Inca term for resettled labourers – which in conjunction with local labourers lead to the creation of mining micro-communities in fairly remote places, such as those recently investigated in the Atacama Desert. This is an excellent early example of how local ore availability has social and economic consequences on a regional scale. As far as Ag is concerned it was exploited both in its native form, from Ag-bearing veins, and also extracted from complex ores. The Inca Empire also had access to Cerro Rico de Potosí, which was until fairly recent times the world's richest silver mine (Cooke *et al.*, 2009).

Use and Mining of Mercury, Copper and Tin

Cinnabar (HgS) and native mercury occurrences of Colombia, Chile and Ecuador have been known since ancient times and one of the largest cinnabar deposits in the world is found at Huancavelica in Peru (Brown, 2001; and references therein). Cinnabar had various cosmetic and ornamental uses in the Inca society in addition to its use for pigment manufacturing, while native mercury was mined between 1400 BC and 1450 AD, reaching its peak around the time of the Incas. However, as the health hazards associated with mercury, which was also used for silver amalgamation, were

realised, the Incas abandoned its use. It is tempting to assume that the coexistence of exploitable gold deposits and exploitable mercury deposits made it possible to produce such vast amounts of gold and silver plated objects. Copper was the earliest metal used in smelting, as evidenced by the copper slags, dated between 900 and 700 BC, which were found in the Highlands of Bolivia. The Incas made extensive use of alloys, namely arsenic bronze and tin bronze, which are alloys of arsenic and copper and tin and copper respectively (Cooke *et al.*, 2009), while evidence of bismuth bronze have been found at Machu Pichu; the existence of Cu-Au and Cu-Ag-Au alloys has also been noted (Cooke *et al.*, 2009). Tin was obtained from the *altiplano* – the Andean Plateau – where cassiterite (SnO_2) occurrences are abundant and it was widely used throughout the Inca Empire. It is still doubtful if the Incas knew of the existence of tin as a pure element, despite using it, in the form of cassiterite, to create alloys (Petersen, 1970).

Discussion and Conclusions

Within the context of the Inca civilisation, it is possible to approach ore mining and processing as a formative factor of social and economic differentiation, which in turn had ritual and religious connotations, as noted by van Gijseghem *et al.* (2013). A principal aspect of any empire's economical policy is the acquisition of revenue, which drives imperial expansion, which in turn leads to a further increase in revenue, in a circular scheme repeated so often in the course of human history. Revenue was extracted by taxation, tribute and plunder, and by intensification of productive activities. The latter can be achieved by infrastructure improvements, technological innovations and new production methods, and local socioeconomic reform. All such measures result in the symbolic and political integration of provinces, which will in turn expedite road construction, administrative infrastructure establishment and as such the imperial control structure will be physically and notionally expanded. From the abovementioned reasoning it becomes evident that the need to increase the influx of ores, and especially of precious metals, was a cardinal factor if not in fuelling directly the expansion of the Inca Empire, then in accelerating the assimilation of provinces rich in specific resources. This trend continued up until the Spanish conquest in 1532, when the abundance of ore deposits was to be in essence the cause of the Empire's collapse. After the discovery of America by Christopher Columbus in 1492, Spain and Portugal, the two great seafaring nations of the 15th and 16th centuries divided the as yet undiscovered or otherwise unexplored world in two, with the Treaty of Tordesillas (McKee, 1987). What followed was arguably one of the most frantic exploration attempts in the history of mankind, influenced in a not inconsiderable degree by tales of immeasurable wealth and of the existence of El Dorado (Harrasta, 2014). However, such vast amounts of treasure were a mixed blessing. On one hand, Spain used them to expand her empire, her military and her navy. On the other hand, it was often that despite the massive influx of precious metals, the Spanish Crown was not capable to pay the soldiers guarding it. Ultimately, the existence of the undefended Spanish galleons off the Peruvian coast prompted the legendary raiding voyage of Sir Francis Drake in 1577 which, in tandem with other covert or apparent acts of hostility paved the way for the war of 1588 between the two nations (McKee, 1987). Of how and why the discovery of the Americas transformed the existing *status quo*, historical conclusions have been reached long ago. What has not been adequately put forth, however, is the importance of the «geological background» in the existential battle of the contemporary nascent empires and colonial powers. For can it be said that had the Americas not possessed such phenomenal natural wealth the Spanish Empire would have so rapidly flourished? Or is it a foregone conclusion that even if such ore deposits existed, albeit being not accessible by the indigenous populations which would consequently be relatively poor, the Spanish would have rushed to such a frenetic conquest, especially given the fierce native resistance and the adverse environmental and geomorphological conditions? It can be therefore concluded that the fortuitous discovery of a new continent so rich in natural wealth was the fulcrum of colonialism and expansionism of the Old World, shaping the course of human history for centuries. It is, accordingly, evident how the interplay between man and geology is a formative factor of human history.

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