**WorldView2 satellite imagery in remote sensing a past gold trading trail in Luzon: testing
Ethnohistory-based and GIS- based models**

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Abstract

This article examines the application of image enhancement techniques on high resolution and multi-spectral WorldView 2 satellite images in aid of remote sensing a past gold trading trail in Northwestern Luzon that was used from the PreSpanish Contact Period 10th to 16th c and the Spanish Contact Period (17th to 19th c). In delineating the corridor for the research, several ethnohistorical accounts were followed as interlocutors. The article posits that segments of the Aringay- Tonglo- Balatok gold trail are still visible on the landscape while other segments may have been converted to contemporary farm-to-market roads. Identification of the segments was made possible by application of image enhancement techniques on WorldView2 satellite imagery including resolution merge using Brovey transform, unsupervised classification using a fusion of built- up index and vegetation index. Satellite band combination for mining operations (yellow-NIR1-red edge), modified false color Infrared (NIR1-green-blue), and soils and constructions (red-blue-yellow) have also been of immense utility.

1. Introduction

This article is part of a long-term research project that looks at the gold *tabu-tabuan/ tiangge* or *evanescent market* (terms coined by Allegre 1998: 148) encounter in Northwestern Luzon Island between the 10th to the early 20th c. For this article the focus is the movement of gold within the present- day provinces of southern Benguet and southern La Union in Luzon specifically from the gold mines of Acupan/ Balatok to Tongo bulking village and eventually to Aringay and Agoo coastal maritime trading center (CMTC). This trade and exchange event is connected to a far-reaching maritime exchange network that span the Indian Ocean and South China Sea (IO-SCS). This belt circulated products such as porcelain, silk, cotton, beeswax, gems, beads, and precious minerals most notably gold. This paper will focus on results using computer-generated GIS modelling and Satellite Imagery analysis.

The article also aligns itself with the middle-range theory in archaeology which proposes that human behavior in the past will be manifested in some way in the modern landscape. This gives us the interesting possibility that extant/ past trails that were used to transport bulked gold in the past may still be in use today. With that in mind, it is possible to reconstruct past trails based on the articulations of present-day trails. The question then is how can GIS and Remote Sensing using WorldView 2 satellite imagery in tandem with ethnohistorical data aid in illuminating past gold trade trails in Southwestern Cordillera? What would be the optimal route for the early Ibaloi gold miners to use? The paper will compare the results of an “ethnohistorical model” and a Least- Cost Path predictive model.

The paper will shed light in the relationship between the lowland, coastal Aringay traders and the interior, upland Ibaloi group. The analysis suggests that the Ibaloi practiced their agency

in the expansive South China Sea gold trade system and were not always subservient to the lowland chiefs (i.e. the Aringay traders were not middlepersons in the transaction all the time). The analysis shows that Ibaloi from Tonglo were in a position to deal with the maritime traders directly without being cut-off from the loop by the lowland coastal chief (middle person). Thus they were able to negotiate their peripherality (Kardulias and Hall 2008, Sheratt and Sheratt 1991) to the South China Sea trading system.

2. Region Background

The Philippine archipelago (**Figure 1**) is a source of interior forest products including spices, tropical hardwoods, abaca cloth, other metal ores, and animal pelts (Junker 1999:222). In exchange for these items, the 12th to 13th c Chinese chronicler Chao Jukua identify the imports as porcelain, black damask, silk, glass beads, lead net sinkers and tin (Hirth and Rockhill 1911:162). It is argued that starting on the 10th c peoples from the Philippine archipelago already established trading relationships with polities overseas including China, Japan, India, Siam, Annam, Malaysia, Indonesia, Khmer, and notably Arabs and Persians reaching its pinnacle between the 12th to the 15th c (Dizon 2004: 1). Luzon became articulated to the South China Sea trading system because of demand for Philippine resources.

Gold was also a prime commodity from the archipelago, notably those mined from the islands of Luzon and Mindanao. The islands may have part of Subvarnhadippa, or “isles of gold”, mentioned in South Indian texts (Lopez 1992). One of the key regions known for gold is Northwestern Luzon (NWL) known for its rich deposits of lode and alluvial gold (Tenrengren 1963, Keesing 1962, Beyer 1948, Wernstedt and Spencer 1967). According to Laufer, *the Wu Hsio Pien* or Ming dynasty record of 1575 (quoted in the *Tung his yang k’ao*) states that the island of “Luzon produces gold, which is the reason of its wealth [.]” (1907:257).

Foreign merchants came with their vessels laden with exotic goods including highly fired ceramics from the mainland for the gold trade (Legaspi 1569, Loarca 1582, Medina 1630, Vega 1609). Indeed, shipwreck data corroborates the notion of an expanded trade in the Early Historical Period. Several shipwrecks in Palawan and Luzon attest to the volume of traffic of merchant vessels that plied the Philippine island- hopping route. Among several shipwrecks off Palawan Island four stand out as particularly loaded with cargo dating to the period: Espanola shipwreck (15th c), Investigator Shoal shipwreck (11th to 12th c), and Lena Shoal shipwreck (15th c) (Dizon 2003:7). As for Luzon itself, special mention is made of San Isidro shipwreck (16th c) and Santa Cruz shipwreck (15th c) off the province of Zambales (ibid). Between 1572 to 1574 at Spanish contact, Juan de Salcedo who was dubbed as “the last conquistador” (Scott 1974:4) together with Martin de Goiti and Antonio Hurtado launched three naval expeditions and exacted as much as 6,997 *taes* of gold (217.61 kg) from the coastal settlements in Northwestern Luzon between 1572- 1574 (Newson 2011: 179- 182).

Investigation of ethnohistorical accounts indicate that there are four gold trail networks within the region of interest and they are grouped based on the present- day provinces where they are located. These are; 1) southern Benguet mines- southern La Union coast, 2) northern Benguet mines to northern La Union coast and southern Ilocos Sur coast, 3) upland Ilocos Sur to central Ilocos Sur coast, and 4) Abra to northern Ilocos Sur coast (**Figure 2**) (Newson 2011, Mateo 2004, Scott 1988, Bagamaspad and Hamada- Pawid 1985).

Some of the sites in these trade networks have received some archaeological investigations. In La Union, an abundance of 14th to 17th c Ming Chinese ceramics and Annamese ceramics were noted in Aludaid site (Tidalgo1979: 11) while sites that exhibited earlier 12th to 13th c Jin and Yuan ceramics include Calincamasan (Tidalgo1979: 11),

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91 **Figure 1** Northwestern Luzon location Map (ASTER GDEM is a product of METI and NASA)

Balingasay (Legaspi 1974: 7-9), Calanutian (Canilao 2015: 31). Similar to Balingasay site, Calanutian site (12th to 16th c) also featured gold tooth pegging among the burials and in one approximately 12-year-old female burial there are also flattened gold sheet orifice covers. Aside from the gold the site also features Indian carnelian beads, Indo-Malaysian beads, Thai ceramics and elephant ivories, Chinese, Khmer and a bulk of Annamese ceramics (Canilao 2015: 31).

2.1 Evanescent Markets

Tabu- tabuan/ tiangge (lit. trans. of tabu is bucket used to measure, originally worked melo shells) or evanescent market encounters (terms coined by Allegre 1998: 148) were common occurrences in the archipelago. Several versions occur all over Mainland and Island Southeast Asia (even in Thailand, Burma, Cambodia along major river ways). These ephemeral/ transient markets are hastily set up on the shores closest to merchant ships for convenience of unloading heavy wares (including ceramics, bronze gongs, ivory, etc...). These markets are ideally set up near riverine delta locations wherein transshipment of goods using smaller boats and rafts is possible. During the *tabu-tabuan* stalls are quickly set up at the shore with different sellers with island products out on display (ibid). The evanescent market can be as short as a day or a few days to a week depending on the arrival of interior traders, and the vessel's itinerary (i.e., see Chao Ju Kua 12th-13th c in Hirth and Rockhill 1911).

The presence of the Ibaloi small- scale miners in coastal evanescent market encounter can be gleaned from various sources (Savellano 2009, Mateo 2004, Scott 1988, Bagamaspad and Hamada-Pawid 1985). Mateo elaborates that “[w]ith their gold and forest products the Igorots would trek via land trails and waterways to Ilocos and Panasinan to the west and Cagayan to the east” (2004:56). At this juncture it should be stated that the present day La Union was formerly

114 divided between Ilocos and Pangasinan. Apparently, gold made lowland provisions accessible
115 for the highland Ibaloi. A Spanish chronicler Andres Mirandaola writes that the natives do not
116 get more than what they need from the ground because this will anger their gold- god named
117 Balitok,

118 Because they say that their god orders them not to take out gold, except on the arrival of
119 foreign vessels. (Mirandaola 1574:224)

120 Thus it is only upon the arrival of foreign vessels that they are induced to work on the mines long
121 enough as to get what they will need for the impending transaction,

122 No one of these Indians has more than a very little gold. For if they get a couple of pairs
123 of earrings and a couple of pairs of bracelets and a pair of anklets for the feet, they do not
124 look for any more, they do not strive to hoard it... If perchance any merchant junk comes
125 (to trade) they buy all the goods in credit, after which, in order to pay, all the village
126 assembles and goes to the mines, in order that no one will dare to touch them, and
127 accordingly get the gold that they have to give. (Rada 1569: 224-225)

128 A spanish Augustinian priest Manuel Carillo also writes in 1756 that,

129 The custom of the Filipinos is to go to the placer or mine and get exactly what is
130 necessary when they want to cover the cost of the tribute or their basic needs, and do not
131 worry about anymore. (273)

132 Based on this passages the Ibaloi gold miners themselves were directly dealing with the foreign
133 merchants themselves. Thus, the evanescent market encounter spontaneously takes place at the
134 costal settlements. But more important for this paper is delineating the trading pathways of the
135 gold trade

Northwestern Luzon Gold Trade Networks

LandSat8 Imagery (2015)
Resolution= 30m
RGB=564

Legend

- ✕ Abra Mines (Present-day)
- ▲ Bulking Villages (EHP)
- ⊗ Ancient Gold Mines (EHP)
- ⚓ Coastal Maritime Trading Centers (EHP)
- Network 4- 4180 sq. mi.
- Network 3- 2331 sq. mi.
- Network 2B- 1624 sq. km.
- Network 2A- 1740 sq.km.
- Network 1 (current study), 1000sq.km

LandSat8 images downloaded from <https://libra.developmentseed.org/>
Credit: U.S. Geological Survey, Department of the Interior/USGS

Prepared by MAPC2016

South China Sea

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137 **Figure 2** Map showing gold trade networks (Credit to US Geological Survey Department of the Interior/ USGS)

138 Visibility then may have been a very important factor in order for the Cordillera miners
139 to spot merchant vessels on the coast. The GIS analysis will show that the bulking village of
140 Tonglo allows for good visibility of Aringay.

141 **2.2 Tonglo- Balatok- Aringay**

142 Otto Scheerer identifies Tonglo village as a pre Spanish Contact gold trading center
143 which was briefly used as a mission center in the 18th c (1975: 198). Scheerer followed the
144 Tonglo descriptions provided by Pedro Vivar an Augustinian priest who unsuccessfully
145 attempted to convert the Ibalois,

146 Tongdo is the largest of the Rancherias know to me; it consists of 220 souls of good
147 friendly people of the most sincere nature encountered by me in this country. The town is
148 situated four leguas east of Cava [Aringay] in a gully formed by a steep mountain, and in
149 an environment that lacks even a small stretch of level space... Hither is brought all the
150 gold that comes dirty from the mines; they refine it somewhat and take it down to the
151 Ilocos for sale, bringing up in return so many buffaloes and cattle (Vivar, as quoted in
152 Scheerer 1975, 184).

153 Based on the account, Tonglo was a gold bulking village. A bulking village is a halfway point
154 between mines and the coastal settlements wherein the gold is partially processed and bulked
155 into ingots or cakes ready for the overseas transport. The existence of bulking stations have been
156 noted in other gold producing islands in Southeast Asia like Sumatra and Borneo (see Dobbins
157 1983 and Harrison 1970). Tonglo has figured in several studies by prominent historians and
158 Cordillera scholars (Prill-Brett, Salinas-Ramos and Follosco 1998, Reyes-Boquiren 1997,
159 Bagamaspad and Hamada- Pawid 1985, Scott 1974, Scheerer 1975). Based on a conjunction of

early historical records with systematic archaeological survey, Tonglo appears to be located on the slopes of Mount Calugong within the vicinity of present day Barangay Taloy Norte, Tuba, Benguet (Canilao 2012: 58- 78) (**Figure 3**).

The question then becomes from which mines did the “dirty” gold ore brought to Tonglo come from? Oral history accounts indicate that the gold comes from Acupan (Scheerer 1975: 202). Indeed it appears that the most proximal past gold mining/ panning area is Acupans specifically the mines of Balatok (from balitok lit. trans. gold and god). In fact, when plotted in a map, the location of Tonglo is the midpoint between Balatok and Aringay (**Figure 4**). Acupan appears in an early map drawn by Father Antolin O.P. dated 1789 (see Scott 1988). Acupan is in the same gold-rich river valley as Antamok called the Virac valley. Antamo[k] mines is also located in this valley and was the site for early gold assaying by Capt. Alonso Quirante (1624: 283).

The final saga in this movement of gold from mines to trading vessels is its journey to Aringay where it is traded with maritime vessels. Aringay is commonly identified as a past settlement based on historical sources and oral tradition sources. Aringay is also a past trading settlement based on oral tradition accounts (Prill- Brett 1998, Bagamaspad and Hamada-Pawid). According to Andres Mirandaola writing in 1574 (223) A[r]ingay was a source of gold in Luzon. Aringay is also included in a list of areas where gold was exasted by conquistador Martin de Goiti in the 16th c (Newson 2009).

3 .Method

Trumboldt argues that an aerial perspective is the earliest and most effective way of discovering and verifying trails on the ground (1991: 7). Snead, Erickson and, Darling (2009)

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183 **Figure 3** *Tonglo in Mount Calugong, westerly view from Tongshu locality in Mount Santo Tomas (photo by author)*

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Figure 4 Note the central location of Tonglo between Balatok and Aringay

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188 state that remote sensing, notably satellite imagery, has revolutionized the study of landscape of
189 movement particularly the study of trails (p. 11). The authors argue that GIS provides predictive
190 modelling of trails, paths, and roads using characteristics of the topography as inputs when
191 physical evidence for these features is lacking (ibid). They cite some of the works (i.e., Madry
192 and Crumley 1990, Madry and Rakos 1996) that utilize cost pathways (2009:11). The authors
193 provide the work of Kantner on Chaco Roads of Lobo Mesa New Mexico wherein he tested the
194 orientation of the trails against a rational pattern of travel (Snead, Erickson and, Darling 2009: 12
195 citing Kantner 1997). Kantner found out that the actual features were a poor fit to the model thus
196 they were more than just functional routes (Snead, Erickson and, Darling 2009: 12). Bell,
197 Wilson, and Wickam (2002) were also able to use GIS methodology for reconstructing routes of
198 communication between past sites in Sangro Valley, Abruzzo, Italy. Madry and Rakos were able
199 to prove the immense utility of using a GIS specifically line-of-sight and cost-surface, and
200 optimum corridor selection modules in understanding the location of Arroux River Valley
201 hillforts and known roads (1996:104). Their “results show a strong correlation of these routes
202 with the visibility from the hilltop defenses (ibid). The authors also argued that an emerging new
203 generation of least cost path GIS analysis (i.e. Harris 2000, Llobera 2000) wherein functional
204 protocols will be shed for more theoretical orientations (2009: 12). Other more recent works on
205 least cost path analysis include Güimil-Fariña and Parcero-Oubiña (2015), Lock Kormann and
206 Pouncett (2014), Herzog (2013), Howey (2011).

207 Satellite images have successfully been used to identify trails in some regions. Satellite
208 images have been used to remotely sense past trading trails in Chaco Canyon (Sever and Wagner
209 2011). The authors started with the objective of examining the relationship between surface and

210 subsurface archaeological features and how this affected the bandwidth on multispectral sensors
211 (Sever and Wagner 2011: 50). Using bands 1, 2, and 3 of the Thermal Infrared Multispectral
212 Scanner, the prehistoric roadways as well as major walled structures and agricultural fields could
213 be seen (2011: 51). Satellite images have also been used in the analysis of past trails in the Near
214 East (Kouchoukos 2001).

215 The work of Sheets and Server (1991) is interesting because they used remote sensing
216 aerial photography and Thermal Infrared Multispectral Scanner in tandem with ground
217 verification in locating prehistoric footpaths in the tropical forests of Costa Rica. The remotely
218 sensed footpaths exhibited some crop mark features associated with the prehistoric trails in some
219 pasture lands and forest areas as well (p. 62). They add, “some of the paths can be seen and
220 followed in the field, as linear depressions, particularly where they transverse slopes steeper than
221 about 3 to 4 degrees” (1991: 62). Later they conclude that the prospects for looking for past
222 footpaths in tropical moist environments is possible using aerial photography (63). I would argue
223 that topographic and ecological features in Northwestern Luzon are slightly more conducive to
224 trails analysis especially the zones between mining areas and bulking villages in the highlands
225 where there are limited patches of pine forests and the rest mainly covered by cogon grass (tiger
226 grass). Patches of deciduous forests are also close to the foothill corridor.

227 The “middle-range theory” in archaeology proposes that human behavior in the past will
228 be manifested in some way in the modern landscape. This theory applies not only in terms of
229 artifact formation but also trail formation or wayfinding/ navigation of people in the past. Thus
230 extant/ past trails that were used to transport bulked gold in the past may still be in use today
231 being incorporated into paved and unpaved foot paths and roadways, perhaps to haul produce.
232 Ferguson, Berlin and Kuwanwisiwma (2009) for instance used trail analysis to argue that past

trails may integrate pedestrian trails, pack animal routes, wagon roads, and modern unpaved roads, which is the case for the Hopi (p. 34). In the Hopi transportation network, trails and roads overlaid one another over time (p. 40). They cite the case of Arizona State Route 264 (p. 26) as an example.

3.1 Ethnohistoric Model and GIS Predictive Model

Two models were created for the Balatok- Tonglo- Aringay gold trading trail. The ethnohistorical model is based on the 1829 account of Don Guillermo Galvey who was the first to suppress the upland Ibaloi into submission to the Spanish colony (**Figure 5**) (Scheerer 1905: 173- 178). The least cost path model on the other hand is based on ASTER global DEM data (**Figure 6**). What is immediately apparent is the disconnect between the ethnohistorical model and the GIS model. What can be stated off-hand is that the trail based on ethnohistoric accounts seems to be directed towards Pugo, which is a bulk breaking point in the Aringay River system. This will be explored in the Conclusion section.

A third GIS model that was created is the visibility model from Tonglo gold bulking village (1,161 meters above sea level) to Aringay coastal settlement which is 16 kilometers to the west. This is being done to support the contention that the gold miners were sighting the vessel arrivals at the coast in order to time their arrivals on the ensuing evanescent market encounter. The analysis shows that Tonglo village as a gold bulking center has a very good visibility of Aringay (**Figure 7**). A three dimensional rendering of the view was also recreated from Tonglo (**Figure 8**). Indeed, the Tonglo observer would be able to spot vessels that are travelling at 1 to 2 knots *en route* to the Aringay CMTC.³ Timing is important for the tabu- tabuan/ tiangge or evanescent market to become successful. For the Ibaloi gold miners who have direct access to

the gold lode veins in Southwestern Cordillera, they have to come down from the mountains as soon as they spot vessels already at or approaching Aringay, thus Tonglo gold bulking center needed to be situated strategically to sight the merchant ships. Interestingly, the amount of time it takes a trading party with bulked gold to hike from Tonglo to Aringay is around half a day based on Guillermo Galvey's account (see Scheerer 1905: 173- 180). Now at this juncture image enhancement will be implemented on WorldView2 satellite imagery to remotely sense trail segments.

3.2. Image Enhancement of WorldView 2 Imagery

A 1,000-square kilometer area covering the Balatok-Tonglo-Aringay trail was provided by DigitalGlobe Foundation. These were culled from three high- resolution, panchromatic and multispectral WorldView-2 satellite scenes (Catalog IDS; 103001002D7C2F00, 103001001F156900, 10300100218C3A00). The three satellite scenes would have to be prepared through the pansharpening tool of *Erdas Imagine 2016 software*. The multispectral layer was subset into band 1(coastal) alone, bands 2 to 6 (blue, green, yellow, red, red edge) stacked, and bands 7 and 8 (NIR1, NIR2) stacked. Band 1 and Bands 7 and 8 were resampled to 50cm. Multispectral bands were first resolution merged with the panchromatic band and later with the three resampled bands 1, 7 and 8. The pansharpened scenes were then subjected to unsupervised classification using four indices namely; WV2 New iron index, WV2 built- up index, WV2 soil index, and WV2 improved vegetation index. Data fusion (2006: 62) was then done whereby the four datasets were then layer stacked together and viewed in a 2 dimensional red- green- blue color composite. The ethnohistorical model and the GIS predictive model were then overlain on the image enhanced WorldView2 scenes and various band combinations were tested to see if

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278 **Figure 5** Map (1837) showing 1829 route of Guillermo Galvey (Courtesy of Archivo General Militar de Madrid)

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Figure 7 Result of Viewshed analysis (ASTER GDEM is a product of METI and NASA, WorldView2 courtesy of Digital Globe Foundation)

Figure 8 Three dimensional rendering of view of Aringay coastal settlement from Aringay (ASTER GDEM is a product of METI and NASA)

trail segment spectral signatures would be enhanced. Three particularly useful combinations include the following: mining operations (yellow-NIR1-red edge), modified false color Infrared (NIR1-green-blue), and soils and constructions (red-blue-yellow).

A closer examination of least cost path routes show that the model lay adjacent and parallel to present day trails along the route from Balatok mines to Tonglo bulking village. This is especially true for segments within the Balatok to Tonglo route found in 51Q 244369mE 1810261mN (**Figure 9a, 9b**) and 51Q 247895mE 1810109mN (**Figure 10a, 10b**). Scenes containing these trail segments were enhanced using the mining band combination. As for the Tonglo bulking village to Aringay coastal settlement model, there are no approximate trails both past as well as contemporary. A closer examination of the ethnohistorical model; however, reveals that there are some past trail segments that scale the peak of the same mountain that Don Guillermo Galvey used in his 1829 expedition. The World View 2 modified infrared combination also enhanced the spectral signature of a trail located in 51Q 229500Me 1809445Mn. Here we can clearly see how the trail has become associated to secondary growth vegetation that grow in a uniform patter. (**Figure 11a, 11b**)

These trail segments were enhanced using several iterations of the datafused WV2 New iron index, WV2 built- up index, WV2 soil index, and WV2 improved vegetation index. The most enhancement seems to was seen in the built-up index, improved vegetation index, improved vegetation index combination (BU i- IV i- IV i). Two segments of the trails were remotely sensed located at 51Q 230821mE 1812529mN (**Figure 12a, 12b**) and 51Q 229146mE 1806792mN (**Figure 13a, 13b**).

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Legend

center coordinates: 51Q229500mE 1809445mN
elevation: 548m

0 12.5 25 50 75 100 Meters

DigitalGlobe
FOUNDATION
Prepared by MAPC2016

Legend

center coordinates: 51Q229500mE 1809445mN
elevation: 548m

0 12.5 25 50 75 100 Meters

DigitalGlobe
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Prepared by MAPC2016

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Legend

center coordinates: 51Q230821mE 1812529mN
elevation: 836m

0 20 40 80 120 160 Meters

DigitalGlobe
FOUNDATION
Prepared by MAPC2016

Legend

center coordinates: 51Q230821mE 1812529mN
elevation: 836m

0 20 40 80 120 160 Meters

DigitalGlobe
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WorldView2 Imagery (2013, 2014)
Pansharpened, 0.46m resolution
Natural band combination (532)

Legend

center coordinates: 51Q229146mE 1806792mN
elevation: 147m

0 20 40 80 120 160 Meters

DigitalGlobe
FOUNDATION
Prepared by MAPC2016

WorldView2 Imagery (2013, 2014)
Pansharpened, 0.46m resolution
Data Fusion (BUI, 4Y, 10Y)

Legend

center coordinates: 51Q229146mE 1806792mN
elevation: 147m

0 20 40 80 120 160 Meters

DigitalGlobe
FOUNDATION
Prepared by MAPC2016

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350 **4. Conclusion**

351 The GIS analysis aided by satellite remote sensing and ethnohistorical research allowed
352 us to visualize the spatial position takings in the social order in the early Luzon gold trade. A
353 triangulation of all these data shows that Ibaloi miners from Tonglo were strategically situated to
354 spot arriving merchant vessels at Aringay and be able to hike downhill in half a day to participate
355 in the ensuing *tabu-tabuan/ tiangge* or evanescent market at the shores near the vessel. Thus the
356 Mirandaola account of gold in Aringay is potentially gold bulked in Tonglo, which came from
357 the lode and placer mines of Acupan/ Balatok which had intermarriages with Tonglo. The
358 historical account has indicated that the subsistence miner only took what was needed from the
359 mines in order to trade for lowland necessities. Interestingly, this was interpreted by the
360 Spaniards as a sign of sloth. Alternatively, this casts light on the fact that the Ibaloi miners were
361 agents who were free to decide how much gold they wanted to bring down to Aringay.

362 The least cost path from Balatok mines to Tonglo bulking village shows that the Ibaloi
363 miners were using the most optimal path which offered least effort when bringing mined gold
364 nuggets to the bulking village. There are no proximal present day trails however that coincide
365 with the least cost path from Tonglo to Aringay. This invites a deeper investigation of the rugged
366 terrain perhaps using other remote sensing techniques like LIDAR imaging, Segments of past
367 and present day trails; however, were illuminated along the ethnohistorical model using Don
368 Guillermo Galvey's account, which originated from the settlement of Pugo. This settlement
369 would qualify as a bulk breaking village wherein bulked products can be transferred into shallow
370 draft canoes or bamboo rafts. Such riverine vessels would be able to navigate up to Aringay

settlement which is the terminus of this river system. In this case then, economies of scale would have been the organizing principle rather than simply cost minimization effort.

The evolution of the Balatok Aringay trail can be surmised to have initially followed an earlier cost minimized model which was able to accommodate single file, pedestrian travel, but which later on transformed into a combination of pedestrian hike and raft travel possibly in lieu of higher bulk exchanges.

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