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Tectonic evolution and copper-gold metallogensis of the Papua New Guinea and Solomon Islands region

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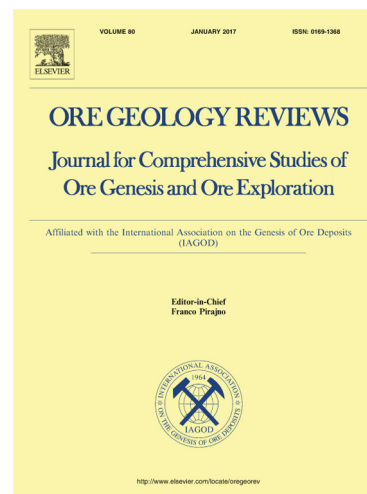
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26 **Abstract**

27

28 Papua New Guinea and the Solomon Islands are in one of the most prospective regions for
29 intrusion-related mineral deposits. However, because of the tectonic complexity of the region
30 and the lack of comprehensive regional geological datasets, the link between mineralization
31 and the regional-scale geodynamic framework has not been understood. Here we present a
32 new model for the metallogenesis of the region based on a synthesis of recent studies on the
33 petrogenesis of magmatic arcs and the history of subduction zones throughout the region,
34 combined with the spatio-temporal distribution of intrusion-related mineral deposits, and six
35 new deposit ages. Convergence at the Pacific-Australia plate boundary was accommodated,
36 from at least 45 Ma, by subduction at the Melanesian trench, with related Melanesian arc
37 magmatism. The arrival of the Ontong Java Plateau at the trench at ca. 26 Ma resulted in
38 cessation of subduction, immediately followed by formation of Cu-Au porphyry-epithermal
39 deposits (at 24-20 Ma) throughout the Melanesian arc. Late Oligocene to early Miocene
40 tectonic reorganization led to initiation of subduction at the Pocklington trough, and onset of
41 magmatism in the Maramuni arc. The arrival of the Australian continent at the Pocklington
42 trough by 12 Ma resulted in continental collision and ore deposit formation (from 12 to 6
43 Ma). This is represented by Cu-Au porphyry deposits in the New Guinea Orogen, and
44 epithermal Au systems in the Papuan Peninsula. From 6 Ma, crustal delamination in Papua
45 New Guinea, related to the prior Pocklington trough subduction resulted in adiabatic mantle
46 melting with emplacement of diverse Cu and Au porphyry and epithermal deposits within the
47 Papuan Fold and Thrust Belt and Papuan Peninsula from 6 Ma to the present day. Subduction
48 at the New Britain and San Cristobal trenches from ca. 10 Ma resulted in an escalation in
49 tectonic complexity and the onset of microplate tectonics in eastern Papua New Guinea and
50 the Solomon Islands. This is reflected in the formation of diverse and discrete geodynamic

51 settings for mineralization within the recent to modern arc setting, primarily related to upper
52 plate shortening and extension and the spatial relationship to structures within the subducting
53 slab.

54

55 **1. Introduction**

56

57 The region of Papua New Guinea and Solomon Islands hosts an abundance of porphyry,
58 epithermal and skarn mineral deposits, such as Ok Tedi, Frieda River, Porgera, Wafi-Golpu,
59 Ladolam (Lihir) and Panguna (Bougainville; Fig. 1; Cooke et al., 2005; Sillitoe, 2010;
60 Richards, 2013). Globally, such mineral-systems account for approximately one-fifth of the
61 world's gold (Au) and nearly three-quarters of the world's copper (Cu) resources (Cooke et
62 al., 2005; Sillitoe, 2010). Formation of these types of deposits is considered to be genetically
63 linked to intermediate to felsic intrusive arc magmatism, typified by regions such as the
64 North American Cordillera, the Andean margin of South America and the Tethyan Belt of
65 Eurasia (e.g. Cooke et al., 2005; Sillitoe, 2010; Richards, 2013; Richards and Holm, 2013;
66 Butterworth et al., 2016). The general relationship between porphyry-epithermal
67 mineralization and subduction zones across the globe implies that there are broad, plate
68 margin-scale tectono-magmatic controls on where and when these deposits form in the crust
69 (e.g. Richards, 2003; Cooke et al., 2005). In particular, changes in the subduction regime are
70 commonly considered as crucial parameters triggering mineralizing events, for example,
71 associated with terrane collisions, subduction of slab structure (e.g., aseismic ridge), or
72 changes in the slab angle during subduction (Cooke et al., 2005; Rosenbaum et al., 2005;
73 Sillitoe, 2010; Rosenbaum and Mo, 2011; Richards, 2013; Richards and Holm, 2013). A
74 detailed understanding of the geological settings linked to deposit emplacement is required
75 when mineral exploration progresses to target concealed deposits beneath cover. This needs

76 to be applied at all scales, but we draw particular attention to the need for an appreciation of
77 regional tectonics and the inherent tectonic complexities that arise through time that may be
78 favorable for deposit emplacement.

79

80 The present-day geodynamic setting of Papua New Guinea and the Solomon Islands is a
81 complex zone of oblique convergence at the boundary between the Australian and Pacific
82 plates, trapped between the converging Ontong Java Plateau and Australian continent (Fig.
83 2). The general tectonic framework of the southwest Pacific has been discussed in previous
84 studies (e.g. Hall, 2002; Schellart et al., 2006), but there are still major uncertainties
85 regarding the complex geodynamics of Papua New Guinea and Solomon Islands (e.g. Hall,
86 2002; Holm et al., 2016). In addition, current geological and ore deposit datasets for this area
87 are inadequate to inform meaningful conclusions. This study takes a high-level approach to
88 this problem by addressing metallogenesis in terms of regional metal endowment and
89 mineralization-styles rather than emphasizing the details of individual deposits or ore system-
90 scale mechanisms for generation of mineral concentrations.

91

92 Recent work investigating the petrogenesis of magmatic arcs throughout the Papua New
93 Guinea and Solomon Islands region (Schuth et al., 2009; Woodhead et al., 2010; Holm and
94 Richards, 2013; Holm et al., 2013, 2015b), combined with regional plate tectonic modelling
95 (Holm et al., 2016), provide a framework for us to develop a regional metallogenic model. In
96 this study we build on the preliminary work of Holm et al. (2015a) to test the hypothesis that
97 subduction-related ore deposits have formed under special circumstances, for example,
98 related to terrane collision, ridge subduction or slab tearing. To achieve this, we combine
99 information on subduction processes and arc magmatism with the distribution of mineral
100 deposits, the styles of mineralization, and the timing of mineralization. We also present new

101 age dates on deposits and prospects. This allows us to provide a more comprehensive
102 regional model for the formation of intrusion-related porphyry and epithermal deposits in the
103 Papua New Guinea and Solomon Islands region through time, with implications for future
104 exploration strategies.

105

106 **2. Tectonic Setting**

107

108 The Papua New Guinea mainland is composed of multiple terranes that were accreted to the
109 northern Australian continental margin during the Cenozoic (e.g. Hill & Hall 2003;
110 Crowhurst et al., 2004; Davies, 2012; Holm et al., 2015b). The result is an accretionary
111 orogen characterized by sedimentary cover rocks on Australian continental crust (Papuan
112 Fold and Thrust Belt; Dow, 1977; Hill and Gleadow, 1989; Craig and Warvakai, 2009),
113 which is buttressed against variably deformed sedimentary, metamorphic and crystalline
114 rocks of the composite New Guinea Mobile Belt (Fig. 2; Dow et al., 1972; Dow, 1977;
115 Hutchison and Norvick, 1980; Hill and Raza, 1999; Davies, 2012). Together the Papuan Fold
116 and Thrust Belt and the New Guinea Mobile Belt comprise the New Guinea Orogen. In
117 contrast, the islands of eastern Papua New Guinea and the Solomon Islands represent island
118 arc terranes formed adjacent to the Australia-Pacific plate boundary (Abbott, 1995; Hall,
119 2002; Lindley, 2006; Holm et al., 2016). More detailed reviews of the regional tectonics can
120 be found in Baldwin et al. (2012) and Holm et al. (2016), and references therein.

121

122 To the east of Papua New Guinea, plate convergence is currently accommodated by
123 subduction of the Australian and Solomon Sea plates at the San Cristobal and New Britain
124 trenches, respectively (Fig. 2). Magmatism associated with these subduction zones occurs in
125 the Solomon arc, the Tanga-Lihir-Tabar-Feni chain and the New Britain arc, overprinting

126 Melanesian arc basement related to earlier subduction at the Melanesian trench (Woodhead et
127 al., 1998; Petterson et al., 1999; Holm et al., 2013). The western extension of the New Britain
128 trench and New Britain arc are the north-dipping Ramu-Markham fault zone, and the West
129 Bismarck arc, respectively (Fig. 2; Abbott, 1995; Woodhead et al., 2010; Holm and Richards,
130 2013).

131

132 Active rifting and seafloor spreading occur in the Bismarck Sea back-arc basin, which
133 comprises the North Bismarck and South Bismarck microplates, separated by the left-lateral
134 strike-slip Bismarck Sea fault (Fig. 2; Denham 1969; Taylor 1979; Cooper and Taylor, 1987;
135 Holm et al., 2016). The Woodlark Basin is an active extensional basin (Fig. 2) that began
136 rifting at ca. 6 Ma (Taylor et al., 1995, 1999; Holm et al., 2016). To the west of the Woodlark
137 Basin oceanic spreading gradually transitions to continental rifting of the Papuan Peninsula
138 (Benes et al., 1994; Taylor, et al., 1995, 1999). Young oceanic crust, including the active
139 Woodlark spreading center, are currently subducting to the northeast at the San Cristobal
140 trench (Mann et al., 1998; Chadwick et al., 2009; Schuth et al., 2009).

141

142 The Papua New Guinea and Solomon Islands region also preserves several subduction zones
143 that are either extinct or accommodate only minor convergence at the present day. The
144 Melanesian trench accommodated southwest-dipping subduction of the Pacific plate beneath
145 the Australian plate and is associated with magmatism of the Melanesian arc (Petterson et al.,
146 1999; Hall, 2002; Schellart et al., 2006; Holm et al., 2013). The location and orientation of
147 subduction beneath the Papua New Guinea mainland that gave rise to the early to late
148 Miocene Maramuni arc (Dow, 1977; Weiland, 1999), is by comparison a more contentious
149 element of the regional tectonics (see Hall and Spakman, 2002; Holm et al., 2015b; Holm et
150 al., 2016, and references therein). Here, we adopt the model that suggests that subduction at

151 the Pocklington trough (and the westward extension thereof into Papua New Guinea) gave
152 rise to tectono-magmatic phenomena within Papua New Guinea and the Maramuni arc (e.g.
153 Dow, 1977; Webb et al., 2014; Holm et al., 2015b). An alternative model invoking
154 subduction at the Trobriand trough will be discussed below. At present, the Pocklington
155 trough marks the southern margin of the Woodlark Basin. The interpreted western extension
156 of this structure includes the Aure-Moresby trough southwest of the Papuan Peninsula (e.g.
157 Ott and Mann, 2015), which forms a suture between the Papuan Fold and Thrust Belt and the
158 New Guinea Mobile Belt (Fig. 2; e.g. Dow et al., 1972; Dow, 1977; Holm et al., 2015b). This
159 proto-Pocklington trough is considered to represent a relict trench that accommodated north-
160 dipping subduction of the Australian plate beneath New Guinea (Hill and Hall 2003; Cloos et
161 al., 2005; Webb et al., 2014; Holm et al., 2015b), but may accommodate some recent
162 convergence (e.g. Ott and Mann, 2015). The Trobriand trough marks the southern margin of
163 the Solomon Sea (Fig. 2), which according to plate reconstructions (Holm et al., 2016), was
164 an active subduction zone during the Pliocene (but not in the Miocene). No arc magmatism
165 has been attributed to subduction at the Trobriand trough.

166

167 **3. Mineral Deposits**

168

169 Research on mineral deposits in the Papua New Guinea and Solomon Islands region has been
170 mainly focused on the nature and controls of individual deposits and their district-scale
171 setting (e.g. Richards and Ledlie, 1993; Hill et al., 2002; Gow and Walshe, 2005; Tapster et
172 al., 2016). To investigate relationships between the evolution of the subduction arcs and the
173 metallogensis of intrusion-related mineral deposits, we used data available from 47
174 Cenozoic intrusion-related Cu-Au deposits (Table 1; Figs. 1 and 3), encompassing active
175 mines, deposits and prospects. Our dataset has information on deposit style and the total

176 deposit endowment, including deposit tonnage, and copper and gold grades (Fig. 3). Metal
177 endowment for each deposit was calculated based on deposit tonnage and metal grade. Data
178 were sourced from recent company reports where possible, and were supplemented by data
179 from Garwin et al. (2005), Singer et al. (2008) and other relevant literature (see Table 1;
180 reported deposit information is not intended as a JORC-compliant category; deposit
181 endowment references are included in the supplementary material).

182

183 The geochronological dataset is supplemented by new radiometric constraints for six
184 deposits. Additional constraints are based on field observations and stratigraphic
185 relationships. Uncertainties within the dataset originate from both parametric sources (quoted
186 uncertainty due to analysis and systematic uncertainties e.g. decay constants), and non-
187 parametric geological uncertainty, for example, the difference between the dated igneous
188 intrusion and the hydrothermal system or alteration episode.

189

190 Mineral deposits throughout the Papua New Guinea and Solomon Islands region range in age
191 from late Oligocene to Quaternary (Table 1; Fig 1). The age of copper and gold mineral
192 deposits in mainland Papua New Guinea ranges from Miocene to Quaternary. These deposits
193 are dominated by porphyry-type deposits, which formed within the New Guinea Orogen (e.g.,
194 Ok Tedi, Frieda River, Porgera, Wafi-Golpu; Fig. 1). Epithermal- and porphyry-type
195 deposits, such as Hidden Valley (Papua New Guinea) and Tolukuma, occur along the Papuan
196 Peninsula and extend east into the Woodlark Basin (Umuna, Misima Island and Woodlark
197 deposits). Commodities throughout mainland Papua New Guinea vary between copper-rich
198 and gold-rich deposits (Figs. 1 and 3). The islands in eastern Papua New Guinea and the
199 Solomon Islands represent island arc settings with deposits ranging from Oligocene to recent
200 ages. These deposits occur as porphyry- and epithermal-type deposits, as well as seafloor

201 massive sulphide (SMS) deposits, with no clear trend in either copper or gold dominated
202 systems (Figs. 1 and 3). Well-known deposits within this region are represented by the high-
203 grade SMS Solwara deposits, and the giant Ladolam (Lihir) and Panguna (Bougainville)
204 deposits.

205

206 **4. Samples and Methodology**

207

208 **4.1 Samples**

209

210 Six rock samples were obtained from mines, deposits and prospects for the purpose of
211 gaining new geochronological constraints on the timing of deposit formation. The chosen
212 samples represent either recently discovered mineralized localities with no timing constraint
213 or historically identified mineral occurrences that have lacked conclusive age dating.

214

215 Two samples (109472a and JD15) are from Papua New Guinea (see Fig. 1). Sample 109472a,
216 from the Ipi River porphyry Cu-Au-Mo and epithermal Au prospect (146.71°E 8.25°S), is an
217 intensely stockworked, altered and mineralized porphyritic andesite. The prospect is located
218 in the Owen Stanley Ranges of the central Papuan Peninsula, approximately 50 km northwest
219 of the Tolukuma mine. Sample JD15 (668956 9341950 UTM AGD66 zone 54S) is from the
220 Baia porphyry Cu-Au prospect located southwest of Porgera within the Papuan Fold and
221 Thrust Belt. The sample is a crystal-rich lapilli tuff of andesitic composition, with complexly
222 zoned plagioclase and minor hornblende in a fine-grained fragmental matrix. Both samples
223 are derived from magmatic occurrences associated with mineralization and represent the
224 probable maximum age for mineralization.

225

226 Sample SI11886 (6°51'49.24"S 156° 5'9.73"E; Turner and Ridgeway, 1982), from Fauro
227 Island in the Solomon Islands, is a porphyritic hornblende-biotite dacite from the calc-
228 alkaline volcanic sequence that was emplaced into a late Oligocene-early Miocene tholeiitic
229 lava sequence associated with earlier Melanesian arc growth (Turner and Ridgeway, 1982). A
230 number of high-grade epithermal Au-Ag prospects are hosted by the dacitic volcanism and
231 likely share a genetic association. The dacitic volcanism has not previously been dated by
232 radio-isotopic methods and no biostratigraphic ages are available, but some authors have
233 proposed a potentially pre-Pliocene age (Turner and Ridgeway 1986).

234

235 The Choe Intrusive complex of southeast New Georgia is host to the Tirua Hill prospect (also
236 known as Hube River). The complex represents a nested sequence of picritic gabbro-
237 microgranite intrusives (Dunkley, 1986) that was emplaced into an island arc picritic basalt
238 volcanic sequence. This sequence represents the earliest stages of island growth linked to
239 initial Woodlark spreading ridge subduction (Rohrbach et al., 2005) so the intrusion age
240 represents a minimum constraint on the timing of this tectonic event. The Tirua Hill Prospect
241 contains minor occurrences of secondary biotite in association with pervasive sericitic and
242 silicic alteration, zones of argillic alteration and a large propylitic halo, in addition to (Au,
243 Ag, Cu, Pb, Zn) sulfide and sulfosalt minerals (Dunkley, 1986). Sample SI1059 (8°28'6.42"S
244 157°47'53.63"E) is a diorite from this zone that postdates the picritic magmatism and
245 contains a stockwork of oxidized pyritic stringers, representing a maximum age for
246 mineralization.

247

248 The Sutakiki prospect is located in central Guadalcanal and lies ~10 km north-northeast of
249 the ca. 1.6-1.45 Ma plutonic Koloula Porphyry prospect (Tapster et al., 2016) and ~10 km
250 south-southwest from the low-sulphidation epithermal Gold Ridge Mine, along the strike of

251 an arc-normal structural corridor (Hackman 1980; Swiridiuk, 1998, Tapster et al., 2011). The
252 prospect is hosted by sheared ophiolitic mafic rocks and limestones and contains a range of
253 high-grade Au epithermal and skarn mineralization and porphyry-style alteration, hosted by a
254 porphyritic intrusion intersected within drill core. Sample SK001_346-346.27m
255 (9°41'26.37"S 160° 4'58.50"E) is a porphyritic hornblende diorite that has weak propylitic
256 alteration and contains minor stringers of pyrite and chalcopyrite, with the age of intrusion
257 taken to represent the maximum age for mineralization but with a close genetic association
258 between magmatic and hydrothermal systems in the area.

259
260 Gold Ridge Mine, Guadalcanal is hosted by a supra-crustal volcanoclastic infill of a fault
261 controlled rhombohedral basin that lies at the north-northeast extent of the arc-normal
262 structural corridor that also contains the Sutakiki and Koloula Prospects (Hackman, 1980;
263 Swiridiuk, 1998). The ore body contains Au, primarily hosted as native Au and electrum,
264 found in association with chalcopyrite, galena, sphalerite, pyrite-marcasite, and arsenopyrite.
265 Two samples, GDC3 279.45 and GDC5 45.8 (9°35'25.90"S, 160° 7'44.01"E), with quartz-
266 adularia-carbonate-sulfide assemblages, probably reflecting the "stage-1" 266-280°C veins
267 (Corbett and Leach, 1998) were selected for Ar-Ar dating of adularia from the upper and
268 lower sections of the orebody that was intersected in recent (2013) drill holes in the
269 Charivunga Gorge Extension.

270

271 **4.2 U-Pb geochronology**

272

273 U-Pb dating was conducted on magmatic zircon grains associated with intrusion-related
274 deposits and prospects. Zircon grains were separated from hand samples or drill cores using
275 standard techniques. They were then handpicked under a binocular microscope and imaged

276 using cathodoluminescence (CL). Zircon U-Pb geochronology analyses for samples from
277 Papua New Guinea were conducted at the Advanced Analytical Centre of James Cook
278 University using a Coherent GeolasPro 193 nm ArF Excimer laser ablation system connected
279 to a Bruker 820-ICP-MS (for methodology, see Holm et al. 2013, 2015b). Zircon grains from
280 the Solomon Islands, with the exception of SI11886, were analyzed for U-Pb geochronology
281 using a Nu Instruments Attom HR single-collector inductively coupled plasma mass
282 spectrometer (HR-ICP-MS) with laser ablation performed by a New Wave Research UP193ss
283 laser (NERC Isotope Geosciences Laboratories, British Geological Survey; see Tapster et al.
284 2014 for methodology). Sample SI11886 was analyzed using a Nu Plasma HR multi-collector
285 ICP-MS, following the methods of Thomas et al. (2016). Further information on data
286 collection, validation and reduction are provided in the supplementary materials.

287

288 **4.3 Ar-Ar geochronology**

289

290 Following sample screening and petrographic studies, Gold Ridge adularia was identified
291 within <2 cm composite veinlets, as <500 μm -sized crystals that are inter-grown with quartz
292 and carbonate minerals. The fine-grained nature of the target minerals and cm-scale vein size
293 that was intercalated with wall rock material required development of a non-standard
294 procedure to extract clean adularia separates for irradiation and Ar-Ar analyses. Samples
295 were initially cut to remove as much of the host material adhered to the vein as possible, this
296 was then leached in a warm bath of weak citric acid to reduce the calcite within the vein and
297 aide disaggregation. The acid was frequently replaced until no effervescence occurred when
298 the fresh acid was introduced. Following hand-crushing, sieving, washing, and
299 electromagnetic separation, non-magnetic fractions 355-500 μm were passed through LST
300 (lithium polytungstates) heavy liquids twice at the required densities to initially remove pyrite

301 and then to remove quartz. The appropriate density fraction was then laid in a grid formation
302 on carbon tape and examined under environmental mode SEM to screen the remaining
303 grains; this was an important step as grains were commonly composite quartz-adularia, or had
304 clear Na peaks, suggesting that the feldspar was likely to be derived from the feldspathic-
305 altered wall rock material rather than primary hydrothermal adularia. The best grains were
306 selected and removed from the carbon tape to form the mineral separate. Mineral separates
307 were irradiated at the Cd-lined McMaster facility, Ontario, Canada, for 5 minutes after being
308 packaged into Al-discs. J values were calculated via the irradiation of Alder Creek Sanadine
309 (1.1891 ± 0.0006 Ma; Niespolo et al., 2016). Samples were analysed at Scottish Universities
310 Environmental Research Council facility, East Kilbride. Full details on the analytical
311 procedures are described in the supplementary information.

312

313 **5. Geochronology Results**

314

315 Results for zircon U–Pb age dating for the selected samples from Ipi River, Baia, Fauro
316 Island, Tirua and Sutakiki are shown in Figure 4, and Ar–Ar adularia ages for Gold Ridge are
317 shown in Figure 5. These final interpreted ages are also included in Table 1. The results do
318 not show evidence for significant isotopic disturbance or mixing of different age domains
319 during zircon ablation, nor is there any significant difference in the age of zircon cores and
320 rims. The complete zircon isotopic data can be found in the supplementary material.

321

322 All interpreted magmatic crystallization ages are Pliocene to Quaternary. Uncertainties are
323 reported at a 2σ level with a minimum uncertainty reported at 0.1 Myr. Sample 109472a from
324 Ipi River yielded a crystallization age of 4.9 ± 0.1 Ma (N=14; MSWD=1.4); sample JD15
325 from Baia returned an age of 1.70 ± 0.1 Ma (N=24; MSWD=1.4). The Tirua Hill sample

326 SI1059 yielded an age of 2.4 ± 0.1 Ma (N=20; MSWD=1.1); the Fauro Island sample,
327 SI11886, returned an age of 3.4 ± 0.2 Ma (N=8; MSWD=2.2); sample SK001_346-346.27m
328 from Sutakiki yielded an age of 1.54 ± 0.1 Ma (N=10; MSWD=1.4).

329

330 The two Adularia bearing vein samples from the Gold Ridge Mine yielded 100% plateau ages
331 of $1.63 \pm 0.05/0.06$ Ma and $1.51 \pm 0.09/0.09$ Ma, (quoted at 1σ with the latter value including
332 decay constant uncertainties) and are indistinguishable within uncertainty. Data precision is
333 controlled by the large degree of atmospheric contamination.

334

335 **6. Plate Tectonic Reconstructions**

336

337 Plate tectonic reconstructions allow us to observe and test relationships between major
338 tectonic events and the location and timing of mineral deposit formation. The reconstructions
339 of this study build on the work by Holm et al. (2015a, 2016) but are extended back to 30 Ma
340 to encompass the main regional ore-forming events. The plate tectonic reconstructions (Figs.
341 6, 7 and 8) were developed using GPLates software (e.g. Boyden et al., 2011; Seton et al.,
342 2012). Plate kinematics were resolved relative to the global moving hotspot reference frame
343 (Müller et al., 2016) using the regional plate motion framework from prior reconstructions
344 (Seton et al., 2012; Holm et al., 2016; Müller et al., 2016). The reconstructions (Figs. 6, 7 and
345 8) are presented in relative reference frames for ease of visualization. These reconstructions
346 were simplified and are mainly aimed at emphasizing major tectonic reorganization events
347 associated with the evolution of the Melanesian arc, Maramuni arc, and New Britain and
348 Solomon arcs. The plate features and rotation files for these reconstructions are available in
349 the supplementary material. The development of detailed plate tectonic reconstructions for
350 the region is beyond the scope of this study.

351

352 A range of datasets and models specific to the Papua New Guinea and Solomon Islands
353 region were incorporated in the reconstructions (see Holm et al., 2016 for details). To extend
354 the plate reconstructions back to 30 Ma, the previous dataset was expanded using constraints
355 on the timing of major plate boundary events (e.g. Cloos et al., 2005; Knesel et al., 2008;
356 Holm et al., 2015b). In this study we make the assumption that subduction of the Pacific plate
357 was occurring at the Melanesian trench from ca. 45 Ma and all upper plates were fixed to the
358 Australian plate motion. Collision of the Ontong Java Plateau with the Solomon Islands at ca.
359 26 Ma (Pettersen et al., 1999; Knesel et al., 2008; Holm et al., 2013) terminated convergence
360 between the Pacific plate and Solomon arc. This collision event, combined with
361 contemporaneous arc-continent collision between the New Guinea Mobile Belt and Sepik
362 Arc in the late Oligocene (not shown; Dow, 1977; Crowhurst et al., 1996), is interpreted to
363 result in a shift of regional convergence to subduction at the Pocklington trough. At this time,
364 the composite New Guinea Mobile Belt terrane and Solomon Sea became fixed to the Pacific
365 plate motion. At ca. 12 Ma, collision of the Australian continent with the New Guinea Mobile
366 Belt closed the Pocklington Sea, but subduction did not initiate at the New Britain-San
367 Cristobal trench until ca. 10 Ma. Because of the limitations of rigid plate behavior we assume
368 that 10 Ma was the timing of complete cessation of convergence at the Pocklington trough
369 and initiation of subduction at the New Britain-San Cristobal trench. After 10 Ma, the New
370 Guinea Mobile Belt and Solomon Sea plate motion were fixed to the Australian plate, until
371 the onset of regional microplate tectonics from ca. 6 Ma (Holm et al. 2016).

372

373 The plate tectonic reconstructions were then correlated with the formation of mineral deposits
374 in time and space. The timing and location of deposit formation is according to Table 1,
375 where these are assigned to 3-million-year time windows. In the following section, we outline

376 the tectonic evolution of the magmatic arcs of the Papua New Guinea and Solomon Islands
377 region, and correlate episodes of mineral deposit formation with major tectonic events,
378 utilizing the plate tectonic reconstructions. The role of structures, both in the upper plate and
379 as slab structures is also introduced, however, this can only be correlated for the active and
380 recent metallogenic systems where we have sufficient insight into the morphology and
381 structure of the subducting plate. Such relationships between tectonics and deposit formation
382 provided by this review of regional metallogenesis can provide a guide to the recognition of
383 similar patterns in ancient convergent margins and serve to inform future exploration
384 strategies.

385

386 **7. Regional Metallogenesis**

387

388 **7.1 Tectonic evolution and metallogenesis of the Melanesian arc**

389

390 The Melanesian arc, comprised of New Britain, New Ireland and Bougainville of Papua New
391 Guinea, and much of the Solomon Islands (e.g. Abbott, 1995; Kroenke, 1984; Petterson et al.,
392 1999), represents the expression of arc magmatism related to subduction of the Pacific plate
393 beneath the Australian plate at the Melanesian trench (Figs. 2 and 6; Petterson et al., 1999;
394 Hall, 2002; Schellart et al., 2006; Holm et al., 2013). The early stages of subduction and arc
395 development are poorly understood due to the paucity of known exposed Melanesian arc
396 rocks and limited studies to date. Since the time of arc formation, however, Melanesian arc
397 basement has undergone complex tectonic reorganizations (Petterson et al., 1999; Hall, 2002;
398 Schellart et al., 2006; Holm et al., 2016).

399

400 The most significant event in the history of the Melanesian arc is the collision of the 33 km
401 thick Cretaceous Ontong Java Plateau with the Australian plate margin in the vicinity of the
402 Solomon Islands (Kroenke, 1984; Petterson et al., 1999) at approximately 26 Ma (Fig. 6;
403 Petterson et al., 1999; Hall, 2002; Knesel et al., 2008; Holm et al., 2013). This collision is
404 interpreted to have caused 1) deceleration of the Australian plate motion (Knesel et al., 2008);
405 2) cessation of sea floor spreading in the Caroline Sea, Solomon Sea, Rennell trough and
406 South Fiji Basin at or around 25 Ma (Davey, 1982; Hall, 2002; Gaina and Müller, 2007;
407 Seton et al., 2016); 3) termination of magmatism in (at least) the western Melanesian arc in
408 the earliest Miocene (Petterson et al., 1999; Lindley, 2006; Holm et al., 2013); and 4) opening
409 of a series of intra-arc basins along the same arc from approximately the late Oligocene
410 (Central Solomon Basin [Cowley et al., 2004; Wells, 1989]; New Hebrides intra-arc basins
411 [Bradshaw, 1992]). Locally in New Britain, an early Miocene extensional regime is inferred
412 from north-northeasterly extensional joint sets and associated hydrothermal activity dated at
413 22–23 Ma (Wilcox et al., 1973; Lindley, 2006).

414

415 Following Ontong Java collision, intense metallogenic activity occurred in the Melanesian
416 arc. Mineral deposits are spatially distributed throughout the Melanesian arc in regions where
417 the arc rocks of this age are outcropping (Fig. 6). The mineral deposits are distributed both
418 adjacent to the site of Ontong Java Plateau collision (Guadalcanal and New Ireland), and
419 distal to collision (New Britain). This suggests that mineralization was likely an arc-scale
420 event rather than a more local process associated directly with plateau collision and stagnant
421 or flat slab subduction (e.g. Kay and Mpodozis, 2001; Rosenbaum et al., 2005). Most
422 deposits are porphyry Cu deposits with subsidiary epithermal deposit types; Au features
423 mainly as a secondary commodity (Fig. 6). It is unclear whether this is a function of
424 exhumation (e.g. erosion of high-level epithermal deposits) and currently exposed crustal

425 levels, or whether this is influenced by the magma composition and localized fluid
426 characteristics. The timing of formation of most Melanesian arc deposits is unfortunately
427 poorly constrained, but based on the known interpreted deposit ages it appears that the main
428 metallogenic episode formed shortly after the collision of the Ontong Java Plateau with the
429 Solomon Islands(ca 24-20 Ma).

430

431 Few studies have investigated the late Oligocene-early Miocene Cu-Au mineralization within
432 the Melanesian arc making it difficult to correlate deposit formation with specific
433 mechanisms within the arc setting. However, post-collision mineralizing intrusions related to
434 formation of the Simuku deposit in New Britain have been shown to hold adakite-like
435 characteristics (e.g. high Sr/Y, HREE depletion; Holm et al. 2013). Such affinities are
436 commonly linked to intrusion-related mineral deposits globally (e.g. Richards, 2011; Loucks,
437 2014). The mechanism for generating these intrusions is not yet conclusive, but Holm et al.
438 (2013) interpreted that the intrusions must have originated from mantle-derived melt at high
439 pressure (i.e. deep crust or mantle) or melting of a garnet-bearing source, such as eclogite or
440 garnet amphibolite of the subducting slab or thickened arc crust (Chiaradia, 2009; Chiaradia
441 et al., 2009; Macpherson et al., 2006; Rapp and Watson, 1995; Richards, 2011; Richards and
442 Kerrich, 2007; Sen and Dunn, 1994).

443

444 **7.2 Tectonic evolution and metallogenesis of the Maramuni arc**

445

446 Following the arrival of the Ontong Java Plateau at the Melanesian trench, at 26 Ma
447 (Pettersen et al., 1999; Knesel et al., 2008; Holm et al., 2013), and late Oligocene arc-
448 continent collision of the Sepik arc terranes onto the northern margin of the New Guinea
449 Mobile Belt (Dow, 1977; Pigram and Davies, 1987; Struckmeyer et al., 1993; Abbott et al.,

1994; Abbott, 1995; Crowhurst et al., 1996; Findlay, 2003), Maramuni arc magmatism
intruded the New Guinea Mobile belt from the early Miocene (Dow et al., 1972; Page, 1976;
Dow, 1977). As outlined above, the subduction that gave rise to the Maramuni arc is
contentious, and we adopt a model of north-dipping subduction at Pocklington trough to the
south of the New Guinea Mobile Belt and Papuan Peninsula (Holm et al., 2015b; a similar
inference was also made by Cloos et al. (2005) and Webb et al. (2014)). However, the extent
of this structure west into Indonesia is unclear. At this time (late Oligocene-early Miocene),
the New Guinea Mobile Belt existed as a ribbon of marginal continental crust (e.g. Crowhurst
et al., 2004) that was rifted from the Australian continent, perhaps somewhat analogous to the
modern-day Lord Howe Rise and Norfolk Ridge in the Tasman Sea. There are no known
significant mineral deposits formed during this first phase of arc magmatism (Fig. 7).

By ca. 12 Ma, convergence at the Pocklington trough and northward drift of the Australian
continent resulted in collision with the outboard New Guinea Mobile Belt and the closure of
the Pocklington Sea (Fig. 7; Cloos et al., 2005; Webb et al., 2014; Holm et al., 2015b). This
event is marked by uplift in the New Guinea Orogen (Hill and Raza, 1999; Cloos et al.,
2005). This change is also manifested in the magmatic record by a transition from medium-K
calc-alkaline arc magmatism at ca. 12 Ma to a marked increase in crustal contribution to the
magmas and less positive ϵ_{Hf} values at ca. 9.4 Ma and 8.7 Ma, interpreted as introduction of
Australian crust into the subduction zone (Holm et al., 2015b). From 12 Ma, growth of the
New Guinea Orogen was driven by shortening and uplift of the New Guinea Mobile Belt and
by accretion of Australian continental platform sediments that initiated the accretionary
complex of the Papuan Fold and Thrust Belt (Hill and Gleadow, 1989; Hill et al., 2002; Cloos
et al., 2005; Holm et al., 2015b).

474

475 Syn-orogenic magmatism of the Maramuni arc was associated with the formation of
476 extensive 12-6 Ma mineral systems throughout mainland Papua New Guinea (Fig. 7). These
477 deposits form a belt proximal to the site of continental collision (Lagaip and Bundi fault
478 zones; Figs. 2 and 7), which forms the suture between the Papuan Fold and Thrust Belt and
479 the New Guinea Mobile Belt (Dow et al., 1972; Dow, 1977; Holm et al., 2015b). The
480 Woodlark deposit, located on the offshore extension of the Papuan Peninsula, is temporally
481 correlative with deposits on mainland Papua New Guinea and is therefore included in this
482 group (Figs. 1 and 7). In general, the earlier deposits associated with this metallogenic
483 episode, which formed at ca. 12 Ma (e.g., Frieda River, Wamum and Woodlark Island),
484 reside in the New Guinea Mobile Belt to the north of the main collisional suture, whereas the
485 later deposits (e.g. Yandera, Kainantu and Wafi-Golpu) reside adjacent to the Lagaip and
486 Bundi suture zones (Fig. 1). This spatial-temporal distribution is in agreement with the
487 interpreted tectonic model of southward migrating arc magmatism (Fig. 2; Davies, 1990) in
488 response to continental underthrusting and slab steepening (Cloos et al., 2005; Holm et al.,
489 2015b). Mainland deposit types are typically porphyry deposits, as opposed to epithermal
490 deposits that occur farther east on the Papuan Peninsula (Fig. 7). This may reflect variation in
491 the level of exhumation and erosion with deeper crustal levels exposed in the New Guinea
492 Orogen related to greater crustal shortening and uplift. In addition, there is also an observed
493 change in the nature of mineral resources, with Cu-Au mineral systems dominating the New
494 Guinea Orogen, whereas Au systems are more dominant farther east on the Papuan Peninsula
495 to Woodlark Island (Fig. 7). This also correlates with a spatial change in the nature of
496 magmatic activity, with medium-K calc-alkaline magmatism of the New Guinea Orogen
497 transitioning to high-K calc-alkaline magmatism in southeast Papua New Guinea (e.g. Smith,
498 1976; Ashley and Flood, 1981; Whalen et al., 1982; Lunge, 2013; Holm et al., 2015b)
499

500 From approximately 7 Ma, uplift of the New Guinea Orogen and the apparent intensity of
501 magmatism accelerated (Hill and Gleadow, 1989; Cloos et al., 2005). Magmatism of this age
502 shows a clear migration to the south, forming a latest Miocene–Quaternary magmatic belt
503 that intruded the Papuan Fold-and-Thrust Belt and the Fly Platform to the south (Fig. 2).
504 Recent and preserved Quaternary magmatism is expressed as widespread large shoshonitic
505 and andesitic stratovolcanoes and intrusive bodies (Page, 1976, Johnson et al., 1978), often
506 spatially controlled by regional-scale structural lineaments (Davies, 1990; Hill et al., 2002).
507 This magmatism is often characterized by a HREE-depleted composition indicative of melt
508 generation or fractionation at high-pressure in the presence of garnet (Holm et al., 2015b).
509 While investigations into the source of this magmatism has been inconclusive to date (e.g.
510 Johnson et al., 1978; Johnson and Jaques, 1980), the most likely scenario is that post-
511 orogenic melting was triggered by adiabatic decompression of the underlying asthenosphere
512 in response to detachment of the stagnated Pocklington slab and collisional delamination at
513 ca. 6 Ma (Cloos et al., 2005; Holm et al., 2015b). The current location of the detached
514 Pocklington slab has not yet been investigated but the recognition of a high-velocity P-wave
515 tomography anomaly beneath northern Australia (e.g. Hall and Spakman, 2002; Schellart and
516 Spakman, 2015) may represent the detached slab.

517

518 Mineral deposits associated with the post-orogenic metallogenic episode are defined by ages
519 of ca. 6 Ma and younger, and include deposits such as Porgera, Ok Tedi and Tolukuma (Fig.
520 7). The spatial distribution of these deposits forms a general belt that reflects the geological
521 setting of the earlier Maramuni arc magmatism but is more continuous along the New Guinea
522 Orogen and Papuan Peninsula when compared to the earlier syn-orogenic deposits (Fig. 7).
523 This behavior may be related to preservation. These post-orogenic deposits generally reside
524 to the south of the 12–6 Ma deposits and are hosted within the Papuan Fold and Thrust Belt

525 and Papuan Peninsula but there is no clear spatial trend related to the age of deposit formation
526 internally within this group. Intrusions related to mineralization are diverse in nature, for
527 example, intraplate alkalic basalts that host the giant Porgera gold deposit (Richards et al.,
528 1990) are distinct within the extensive shoshonitic and high-K calc-alkaline post-orogenic
529 magmatism (e.g. Smith, 1976, 1982; Johnson et al., 1978; van Dongen et al., 2010a; Holm
530 and Poke, 2018). These differences highlight unexplained discrete geochemical domains
531 within what appears to be a continuous magmatic belt. Deposits of this age are diverse and
532 represented by porphyry and epithermal deposits with some related mineralized skarn
533 systems. There is no clear preferred commodity type observed for the post-orogenic deposits.
534 Gold deposits are widespread, particularly to the east (in the Papuan Peninsula). However, Cu
535 appears to become more important in the central New Guinea Orogen with deposits such as
536 Ok Tedi, Star Mountains and Baia (Fig. 7).

537
538 In comparison to the subduction model presented here, the alternative model invokes
539 southwest-dipping subduction at the Trobriand trough to the north of New Guinea from the
540 late Oligocene (Crowhurst et al., 1996; Hill and Raza, 1999; Hall, 2002). The interpretation of
541 the Trobriand trough and associated plate margin geometry has taken various forms (Fig. 7;
542 e.g. Davies et al., 1987; Lock et al., 1987; Hall, 2002; Schellart et al., 2006; Davies, 2012;
543 Seton et al., 2016). Arc-continent collision at the Trobriand trough plate boundary, often in
544 combination with the sinistral transpression across northern New Guinea (Fig. 7), is then
545 linked to the ongoing formation of the New Guinea Orogen and associated mineral deposit
546 formation. However, given the late Oligocene age of initial docking of the Sepik arc terranes
547 at the northern New Guinea coast, there is a large disconnect in time (and indeed in space)
548 between the interpreted collision event and the onset of orogenesis and mineral deposit
549 formation from 12 Ma. Together with the recent findings from Cloos et al. (2005), Webb et

550 al. (2014), and Holm et al. (2015b), this supports the use of the Pocklington trough
551 subduction model over that of the Trobriand trough.

552

553 **7.3 Tectonic evolution and metallogenesis of the New Britain and Solomon arcs**

554

555 Following collision of the Australian continent with Papua New Guinea and cessation of
556 subduction at the Pocklington trough (Cloos et al., 2005; Holm et al., 2015b) by ca. 10 Ma,
557 the regional tectonics had undergone reorganization and convergence was established at the
558 New Britain and San Cristobal trenches (e.g. Petterson et al., 1999). This period of tectonic
559 reorganization is characterized by the ongoing development of regional microplate tectonics,
560 marked by rapid changes in the plate kinematics of discrete terranes and the localized,
561 simultaneous development of extensional and contractional tectonics.

562

563 Retreat of the western New Britain trench from ca. 6 Ma led to back-arc extension and rifting
564 that initiated formation of the Bismarck Sea (Taylor, 1979; Holm et al., 2016). Anticlockwise
565 rotation of the Solomon Sea, linked to hinge retreat at the western New Britain trench
566 (Wallace et al., 2014; Ott and Mann, 2015; Holm et al., 2016), resulted in decoupling of the
567 Solomon Sea plate from the Australian plate, which initiated minor underthrusting of the
568 Solomon Sea plate at the Trobriand trough (Holm et al., 2016), and rotational extension and
569 rifting in the Woodlark Basin from ca. 6 Ma (Taylor et al., 1999; Wallace et al., 2014; Holm
570 et al., 2016). This period of tectonic reorganization from ca. 10 to 6 Ma reflects an overall
571 setting dominated by extensional tectonics that does not seem to be linked to known mineral
572 deposits.

573

574 Subduction of the active Woodlark spreading center at the San Cristobal trench from ca. 5 Ma
575 had important implications for the geological evolution of the Solomon Islands (Chadwick et
576 al., 2009; Holm et al., 2016). The timing for initial ridge subduction overlaps with the onset
577 of crustal shortening across the Solomon Islands and convergence at the North Solomon
578 trench adjacent to the Ontong Java Plateau (Petterson et al., 1997, 1999; Cowley et al., 2004;
579 Mann and Taira, 2004; Phinney et al., 2004; Taira et al., 2004; Holm et al., 2016). Subduction
580 of the spreading center adjacent to the central Solomon Islands also caused extensive arc
581 magmatism, which included high-Mg andesites and adakite-like geochemical signatures
582 (Mann et al., 1998; Chadwick et al., 2009; Schuth et al., 2009). This was exemplified by
583 formation of the New Georgia group of islands that coincide with the location of spreading
584 ridge subduction (Fig. 8; Petterson et al., 1999; Chadwick et al., 2009; Schuth et al., 2009;
585 Holm et al., 2016), and host the Tirua, Mase and Kele River deposits (Figs. 1 and 8a).
586 Reconstructions show that the New Georgia islands and associated ore deposits have been
587 located adjacent to the subducting spreading center since at least the middle Pliocene (Fig.
588 8a). The first absolute geochronological constraints from this area (Tirua Hill; Fig. 4) indicate
589 that mineralization occurred around 2.4 Ma. Cross-cutting relationships with island arc
590 picrites, which signify the effects of spreading ridge subduction on the arc magmatism,
591 indicate that mineralization must post-date initial spreading ridge subduction. The slab
592 window generated by spreading ridge subduction is potentially the cause of one of few
593 currently active volcanic centers in the Solomon arc and a potentially mineralizing
594 hydrothermal system at Savo Island (Smith et al., 2009, 2010, 2011). This suggests a
595 prolonged (~2.5 Myr) influence of direct ridge subduction on magmatism and the formation
596 of mineral deposits.

597

598 In addition to spreading center subduction, a correlation also exists for the location and
599 timing of deposit formation with subduction of the Woodlark Basin marginal structures.
600 Mineralization on Guadalcanal, at the southeast margin of the Woodlark Basin, occurred at
601 ca. 1.6 Ma, approximately contemporaneously with the emplacement of the Koloula
602 Porphyry Complex (1.6-1.45 Ma; Tapster et al., 2016), Sutakiki epithermal-porphyry
603 prospect (1.5 Ma) and Gold Ridge low sulfidation epithermal deposit (1.6-1.5 Ma; Fig. 8b)
604 along an arc-normal (NNE-SSW) transpressive structural corridor in central Guadalcanal
605 (Hackman, 1980; Swiridiuk, 1998; Tapster et al., 2011, 2016). Given the nature of described
606 fault-intrusion relationships at Koloula, the arc-normal deformation that controlled
607 mineralization along the corridor was only active shortly before 1.6 Ma and had terminated
608 by ca. 1.5 Ma (Tapster et al., 2016). The close temporal association of porphyry to epithermal
609 deposits (~100 kyrs) along a spatial corridor that extends over 30 km preclude a direct
610 genetic link between deposits and highlight the critical role that short-lived upper plate
611 structures can have on controlling mineralization. The central NNE-SSW corridor in
612 Guadalcanal runs parallel to a similar set of lineaments in the west of the island, currently
613 under a much thicker Pliocene-Pleistocene volcanic cover. The orientation of structures
614 across the island and their coincidence with the subduction of the southeast margin of the
615 Woodlark Basin (Fig. 8b) suggests that there may be a relationship between the upper-plate
616 structure and subducting topographic high (Tapster et al., 2011). Subduction of the young,
617 hot and buoyant Woodlark Basin crust potentially acted as an indenter, generating structural
618 controls for magma emplacement and mineralization. A similar relationship exists for the
619 location of subduction of the northwest margin of the Woodlark Basin and formation of the
620 Panguna and Fauro Island deposits in the adjacent overriding plate at ca. 3.5-3.4 Ma (Fig. 8a).
621

622 Farther west, the Tabar-Lihir-Tanga-Feni island arc chain of eastern Papua New Guinea hosts
623 the Ladolam, Simberi and Kabang deposits. In this area, differential plate motion between the
624 Solomon Islands and the North Bismarck microplate resulted in intra-arc extension between
625 the islands of New Ireland and Bougainville (Holm et al., 2016). An extensional origin for the
626 Tabar-Lihir-Tanga-Feni island arc chain is supported by geochemical studies, which
627 suggested that the volatile-rich, silica-undersaturated, high-K calc-alkaline basaltic lavas
628 were produced by adiabatic decompression melting of subduction-modified upper mantle
629 (Patterson et al., 1997; Stracke and Hegner, 1998). This region therefore represents an upper
630 plate extensional setting, contemporaneously with tearing of the subducting Solomon Sea
631 slab (Fig. 8c; Holm et al., 2013). The reasons for development of the slab tear are not
632 understood, but tears in the subducting slab such as this are interpreted to promote increased
633 fluid flux and metal transport within the mantle, resulting from a larger exposure of the
634 subducting slab to the surrounding asthenospheric mantle (Richards and Holm, 2013). From
635 this setting it cannot be conclusively determined which of the two settings, upper plate
636 extension, or tearing of the subducted slab, contribute more to potential formation of mineral
637 deposits. However, correlation in the location of the Ladolam deposit above the interpreted
638 slab tear at the time of formation suggests that it was a combination of the two factors that
639 likely contributed to mineralization.

640
641 In the Bismarck Sea, the Solwara deposits of the eastern Bismarck Sea region lie along the
642 Bismarck Sea fault, a transtensional structure that accommodated sinistral motion between
643 the North and South Bismarck microplates as well as opening of the Manus Basin (Figs. 1
644 and 8c; Taylor, 1979; Martinez and Taylor, 1996; Holm et al., 2016). This setting is similar to
645 that of the Tabar-Lihir-Tanga-Feni island arc chain outlined above, where occurrence of a
646 dilational upper plate structure likely acted as a preferential conduit that promoted

647 subduction-related magma flux (Figs. 8c). This example emphasizes the important role of
648 upper plate extension in localizing deposit formation. Preservation is also a major factor for
649 the Solwara seafloor massive sulfide deposit, where the high-grade, small tonnage nature of
650 the deposit type is susceptible to erosion or burial beneath younger sediments.

651

652 **8. Discussion**

653

654 Mineral deposit exploration methodology is currently undergoing new developments driven
655 by large databases and advances in technological capabilities (e.g. Cawood and
656 Hawkesworth, 2015; Butterworth et al., 2016). Such models provide a useful regional context
657 for deposit formation and an understanding of the large-scale conditions under which deposits
658 are likely to form. However, at a smaller scale there are always exceptions to these conditions
659 that arise from dynamic geological settings. For example, in the southwest Pacific and
660 Southeast Asia episodes of continental accretion took place throughout the Cenozoic
661 (Audley-Charles, 1981; Petterson et al., 1999; Hill and Hall, 2003; Holm et al., 2013; Holm
662 et al., 2015b), and microplate tectonics has been active at ever smaller scales (Wallace et al.,
663 2004; Holm et al., 2016). Through combining our knowledge of plate boundary-scale
664 processes with inherent regional- and district-scale aberrations in these Earth systems we can
665 advance our understanding of metallogenesis and achieve greater success in mineral
666 exploration.

667

668 Comparison of the location, timing, metal content and the frequency of mineral deposit
669 formation/occurrence with episodes of tectonic reorganization (Fig. 9) reveals a strong
670 correlation. Melanesian arc metallogenesis (ca. 24-20 Ma), related to collision of the Ontong
671 Java Plateau and cessation of subduction at the Melanesian trench, was a Cu-rich but

672 relatively minor event in terms of total known metal endowment. In contrast, the overprinting
673 West Bismarck, New Britain and Solomon arcs host Cu-Au mineral deposits that formed
674 during a distinct metallogenic episode from ca. 6 Ma and became decisively Au-rich from ca.
675 3 Ma (Fig. 9). This may represent a major episode of intrusive activity and metal-endowment
676 within the region, which was linked to the onset of regional microplate tectonics from ca. 6
677 Ma. Correlation of the New Guinea Orogen metallogenesis with regional tectonics reveals
678 two discrete episodes of deposit formation related to different tectonic events. The first
679 deposit-forming event related to Australian continental collision, waning medium-K calc-
680 alkaline Maramuni arc magmatism and orogenesis from ca. 12 Ma up to 6 Ma has a large
681 copper-rich mineral endowment but few known deposits (Fig. 9). The later deposit-forming
682 event from ca. 6 Ma may have occurred in response to crustal delamination. It is
683 characterized by a large number of known deposits related to high-K calc-alkaline to
684 shoshonitic (and minor intra-plate alkalic) magmatism, but these represent a smaller
685 endowment in comparison to the 12-6 Ma event, with no clear preference in commodity.
686 There is no correlation between the composition of the magmatism and occurrences of
687 mineralization with a broad compositional spectrum from medium-K calc-alkaline through to
688 shoshonitic intrusives and even intra-plate alkalic compositions related to deposits in the New
689 Guinea Orogen and Papuan Peninsula; adakitic compositions, however, are commonly linked
690 to mineral deposits throughout the islands of eastern Papua New Guinea and the Solomon
691 Islands. Importantly, formation of deposits does occur over narrow time intervals that suggest
692 association with regional and discrete tectonic events, such as those interpreted to occur in
693 association with subduction at the Pocklington trough.

694

695 An evaluation of the nature and variability of the diverse geodynamic settings for deposit
696 emplacement through time, and the relationship with the southwest Pacific magmatic arcs

697 and associated subduction dynamics, can provide crucial insights into the array of deposit
698 settings at ancient convergent margins. For example, given current plate motion and
699 convergence rates, it is expected that the Ontong Java Plateau will collide with the Australian
700 continent in approximately 20 million years, resulting in a vast orogen along northeast
701 Australia. The orogen will comprise accreted and highly strained terranes that include the
702 island arcs of eastern Papua New Guinea and the Solomon Islands, and the already composite
703 terranes of mainland Papua New Guinea. In this orogen, the different episodes of mineral
704 deposit formation described above will likely be superimposed on one another. This
705 underscores the importance of recognizing different terranes and tectonic complications in
706 present-day convergent margins, such as the southwest Pacific, to successfully unravel
707 ancient collisional margins such as the North American Cordillera (e.g. Sillitoe, 2008) or the
708 Tasmanides of eastern Australia (e.g. Cooke et al., 2007; Glen et al., 2007). This study
709 provides a benchmark for our understanding of the tectonic evolution and metallogensis of
710 Papua New Guinea and the Solomon Islands, and an analogue with which to compare
711 complex convergent margins globally. By developing such an understanding of the intricacies
712 and aberrations that exist within convergent margin tectonics we can further develop and
713 refine regional exploration models.

714

715 **9. Conclusions**

716

717 A strong correlation between deposit formation and episodes of tectonic reorganization is
718 interpreted for the Papua New Guinea and the Solomon Islands region. The first metallogenic
719 event is result of collision of the Ontong Java Plateau with the Solomon Islands at ca. 26 Ma
720 and correlates with formation of copper-rich mineral deposits throughout the Melanesian arc
721 between ca. 24 and 20 Ma. Subsequent collision of the Australian continent with Papua New

722 Guinea at ca. 12 Ma resulted in two discernible metallogenic events: 1) formation of ca. 12-6
723 Ma copper-rich mineral deposits associated with medium-K to high-K calc-alkaline
724 magmatism and development of the New Guinea Orogen, and 2) formation of ca. 6-0 Ma
725 gold and copper mineral deposits related to delamination of the stagnated slab following
726 collision, and genetically linked to diverse high-K calc-alkaline and alkaline magmatic
727 compositions. The emergence of microplate tectonics in eastern Papua New Guinea and the
728 Solomon Islands from ca. 6 Ma resulted in highly dynamic and discrete kinematic settings
729 throughout the region. Prospective settings for gold-rich deposit formation are interpreted to
730 be related to the localization of mineralized corridors above tearing of a subducted slab and
731 development of slab windows, or upper plate structures related to extension or shortening that
732 promote magma-flux from the underlying mantle and act as an upper plate conduit for fluid-
733 flow (e.g., eastern Bismarck Sea Fault). These findings suggest that a good understanding of
734 geodynamic settings through time, both on the scale of regional subduction zones and
735 district-scale structure, have the potential to contribute to prospectivity studies and the
736 generation of new exploration targets at regional scales.

737

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739

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751

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Figure Captions

1282

1283

1284 **Figure 1.** Mineral deposits of the Papua New Guinea and Solomon Islands region. Red points
1285 indicate deposits and prospects host to samples dated in this study.

1286

1287 **Figure 2.** Tectonic setting of Papua New Guinea and Solomon Islands. A) Regional plate
1288 boundaries and tectonic elements. Light grey shading illustrates bathymetry <2000 m below
1289 sea level indicative of continental or arc crust, and oceanic plateaus. The New Guinea Orogen
1290 comprises rocks of the New Guinea Mobile Belt and the Papuan Fold and Thrust Belt;
1291 Adelbert Terrane (AT); Aure-Moresby trough (AMT); Bougainville Island (B); Bismarck Sea
1292 fault (BSF); Bundi fault zone (BFZ); Choiseul Island (C); Feni Deep (FD); Finisterre Terrane
1293 (FT); Guadalcanal Island (G); Gazelle Peninsula (GP); Kia-Kaipito-Korigole fault zone
1294 (KKKF); Lagaip fault zone (LFZ); Malaita Island (M); Manus Island (MI); New Britain
1295 (NB); New Georgia Islands (NG); New Guinea Mobile Belt (NGMB); New Ireland (NI);
1296 Papuan Fold and Thrust Belt (PFTB); Ramu-Markham fault (RMF); Santa Isabel Island (SI);
1297 Sepik arc (SA); Weitin Fault (WF); West Bismarck fault (WBF); Willaumez-Manus Rise
1298 (WMR). Arrows indicate rate and direction of plate motion of the Australian and Pacific
1299 plates (MORVEL, DeMets et al., 2010); B) Pliocene-Quaternary volcanic centres and
1300 magmatic arcs related to this study. Figure modified from Holm et al. (2016). Subduction
1301 zone symbols with filled pattern denote active subduction; empty symbols denote extinct
1302 subduction zone or negligible convergence.

1303

1304 **Figure 3.** Grade vs tonnage plots for A) gold and B) copper for mines, deposits and prospects
1305 with reported resources. Note logarithmic scale for metal grades and tonnage; data are listed
1306 in Table 1.

1307

1308 **Figure 4.** U-Pb dating results for A) Ipi River 109472a; B) Baia JD15; C) Tirua Hill SI1059;
1309 D) Fauro Island SI11886; and E) Sutakiki SK001346.

1310

1311 **Figure 5.** Ar-Ar dating results for Gold Ridge samples GDC5 45.8m and GDC3 279.45m.

1312

1313 **Figure 6.** Tectonic reconstruction for collision of the Ontong Java Plateau with the
1314 Melanesian arc and deposit formation for 30 Ma and 26-20 Ma. Green regions denote the
1315 present-day landmass using modern coastlines; grey regions are indicative of crustal extent
1316 using the 2000 m bathymetric contour. The reconstruction is presented here without a specific
1317 reference frame for ease of visualization, please see the reconstruction files in the
1318 supplementary material for specific reference frames.

1319

1320 **Figure 7.** Tectonic reconstruction for the period 20-0 Ma, illustrating collision of the
1321 Australian continent with the New Guinea Mobile Belt versus the Hall (2002) reconstruction
1322 model of Trobriand trough subduction. Syn-orogenic deposit formation from 12-6 Ma, and
1323 post-orogenic formation from 6-0 Ma are shown for correlation. Green regions denote the
1324 present-day landmass using modern coastlines; grey regions are indicative of crustal extent
1325 using the 2000 m bathymetric contour. The reconstruction is presented here relative to a fixed
1326 Australia reference frame for ease of visualization, please see the reconstruction files in the
1327 supplementary material for specific reference frames.

1328

1329 **Figure 8.** Selected tectonic reconstructions and mineral deposit formation for key areas and
1330 times within the eastern Papua New Guinea and Solomon Islands region. A) Formation of the

1331 Panguna and Fauro Island Deposits above the interpreted subducted margin of the Solomon
1332 Sea plate-Woodlark Basin, and Mase deposit above the subducting Woodlark spreading
1333 center; B) Formation of the New Georgia deposits above the subducting Woodlark spreading
1334 center, and Guadalcanal deposits above the subducting margin of the Woodlark Basin; C)
1335 Formation of the Solwara deposits related to transtension along the Bismarck Sea fault above
1336 the subducting Solomon Sea plate, and deposits of the Tabar-Lihir-Tanga-Feni island arc
1337 chain related to upper plate extension (normal faulting indicated by hatched linework
1338 between New Ireland and Bougainville), while the Ladolam deposit forms above a tear in the
1339 subducting slab. Interpreted Solomon Sea slab (light blue shaded area for present-day) is
1340 from Holm and Richards (2013); the reconstructed surface extent or indicative trend of slab
1341 structure is indicated by the dashed red lines. Green regions denote the present-day landmass
1342 using modern coastlines; grey regions are indicative of crustal extent using the 2000 m
1343 bathymetric contour. The reconstruction is presented here relative to the global moving
1344 hotspot reference frame, please see the reconstruction files in the supplementary material for
1345 specific reference frames.

1346

1347 **Figure 9.** Mineral endowment for Papua New Guinea and Solomon Islands through time.
1348 Total contained Cu and Au tonnage are shown at time of deposit formation, with number of
1349 deposits in 3 Myr bins. Deposits are differentiated into the island arc terranes for the
1350 Melanesian, West Bismarck, New Britain and Solomon arcs, and the New Guinea Orogen
1351 with deposits related to the Maramuni arc.

1352

1354 **Tectonic evolution and copper-gold metallogensis of the Papua New**

1355 **Guinea and Solomon Islands region**

1356

1357 Robert J. Holm, Simon Tapster, Hielke A. Jelsma, Gideon Rosenbaum, Darren F. Mark

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1359

1360 • We provide a new model that explains the timing and location for deposit formation.

1361 • Deposit formation is linked to collision events and onset of microplate tectonics.

1362 • Six new ages for mineral deposits are provided.

1363 • A comprehensive database of mines, deposits and prospects is included.

1364

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