Ana Maria Dreher · Silvio Roberto Farias Vlach · Sergio Luiz Martini

Discussion on “Gold deposits of the Tapajós and Alta Floresta Domains, Tapajós-Parima orogenic belt, Amazon Craton, Brazil” by Santos JOS, Groves DI, Hartmann LA, Moura MA, McNaughton NJ

(Mineralium Deposita 36:278–299, 2001)

Received: 13 December 2001 / Accepted: 13 December 2001 / Published online: 18 June 2002
© Springer-Verlag 2002

Keywords Epithermal · Gold · Tapajós province · Amazon craton · Brazil

Concerning the recently published article by Santos et al. (2001), we would like to congratulate the authors in their effort to unravel the geological evolution of such a large and poorly known area of Brazil. As to the gold deposits of this region, we want to discuss some aspects about the deposits that Santos et al. (2001) describe as “intrusion-related epizonal quartz vein deposits” and in which they challenge our classification of two of these deposits (Dreher et al. 1998) as adularia-sericite epithermal types.

Firstly, we think it is appropriate to mention that our paper (Dreher et al. 1998) was written about 5 years ago and may contain typical uncertainties when given the level of knowledge available at that time on the Tapajós region geology, with particular reference to hard rock gold deposits. Having said that, we nevertheless stress that our paper was among the first to propose an epithermal origin for Proterozoic gold deposits of the Tapajós province. The Davi and Joel prospects, for instance, had been previously regarded as mesothermal (e.g., Pastana et al. 1994; Bastos Leal and Tassinari 1994). Santos et al. (2001) criticize our epithermal classification for these two deposits and include them in their “Korean-type intrusion-related group.” They fail to mention, however, that we consider the prospects as deep epithermal occurrences. This is particularly relevant here because the deeper parts of adularia-sericite epithermal systems may display features that resemble some of those that are characteristic of intrusion-related deposits (e.g., Robert et al. 1997). Other features may be different when compared with shallower, perhaps more classical, epithermal deposits (e.g., Hedenquist et al. 2000), but, despite this, the deeper deposits still maintain the basic characteristics of the epithermal group, as discussed below.

An important point relates to the adularia content of the prospects. Santos et al. (2001) indicate that minor adularia is present in the Joel and Davi prospects. Underground workings at Davi, however, allowed us (Martini and Dreher 1996; Dreher et al. 1998) to verify that the main vein possesses a decimeter- to meter-scale alteration envelope containing patches and veinlets of reddish feldspar, which were later identified as hematite-altered albrite and adularia. The amount of adularia is not minor. The mineral is an essential phase of a sizable alteration zone, particularly when considering that the main vein itself is never more than 50 cm in width. At the Joel prospect, adularia is not as abundant, but it occurs locally as a light pink or white mineral and may easily be mistaken for carbonate or quartz. In addition, it is well known that the scarcity or even absence of adularia, which is definitely not the case at the Davi and Joel occurrences, can not be used to disprove an epithermal origin for deposits (e.g., White and Hedenquist 1996).

Santos et al. (2001) also state that the epizonal gold of the Tapajós domain lacks many of the characteristics of epithermal deposits and refer to their Table 6 (Santos et al. 2001, p. 292) to prove this point. They mention, for instance, the absence of pencontemporaneous volcanic rocks. Epithermal deposits are, in fact, mostly associated with volcanic rocks, but they may also occur in other rock types at epizonal levels. Examples include gneissies (Tosdal and Smith 1987), metamorphosed basement rocks (White and Hedenquist 1989), intermediate to silicic intrusive rocks (Taylor 1995), and, actually, any rock type forming the basement to a volcanic regime (White and Hedenquist 1990; Robert et al. 1997). Also the geological setting of the prospects is referred to as hypabyssal and this is supposedly inadequate for epithermal deposits. However, in terms of depth, hypabyssal is synonymous with subvolcanic (Jackson 1997), which is indicated by Santos and co-authors in Table 6 itself as an appropriate setting for epithermal adularia-sericite deposits.

Santos et al. (2001) further mention that alteration in the deposits is restricted to a few meters from the ores. This does not seem relevant for the definition of the specific deposit type. According to Sillitoe (1993), low-sulfidation epithermals are characterized by “commonly restricted and visually subtle” alteration zones. Other workers (e.g., Panteleyev 1988; Hedenquist et al. 2000) have noted that the areal extent of alteration zones surrounding
adularia-sericite epithelial deposits tends to be proportional to that of
to nearby orobodies. The one exception is possibly the argillic zone,
within the upper parts of this type of deposit, which may attain a width of one to two orders of magnitude greater than the
contained gold-bearing zone.

We concede that, on the other hand, only part of the mineral
assemblage present in low-sulfidation epithelial gold deposits was
observed in the prospects, although we do mention the presence of
native silver in the Joel occurrence (see Dreher et al. 1998, p. 398).

As for other “missing” ore or alteration minerals, this could con-

crably reflect their lack of identification to date, or the fact that
phasessuchaseilenites, cinnabar, kaolinite and alunite are usu-
ally absent in the deep parts of low-sulfidation epithelial deposits
(e.g., Hedenquist et al. 2000), as we proposed in our model for the

Davi and Joel prospects. Minerals such as sericite (as opposed to
ilite), carbonates, chlorite, and albite (e.g., propylitization), which
are commonly found in deep epithelial deposits, were identified at
the prospects. As to the apparent differences in metal association
mentioned in Table 6 of Santos et al. (2001), these may be again a
function of the depth within the hydrothermal system, where
deep parts lack anomalous Hg, Sb, and As and are enriched in
base metals (Hedenquist et al. 2000).

Santos et al. (in their Table 6, 2001) also introduced our data on
fluid inclusion temperatures. As shown, the temperatures obtained by us (220-
340°C; Dreher et al. 1998) overlap significantly with the higher
ones typical of epithelial gold deposits. We see the temperature
overlap as another good indicator of a deep epithelial situation.

Santos et al. (their Table 6, 2001) present Au:Ag ratios of 2:5:1
for Davi and Joel. If this is really representative of the average ore
of the prospects, and not just determined from grab samples, then
it is still a valid number for adularia-sericite epithelial deposits,
in which maximum values for this ratio may reach 10:1 (Robert et al.
1997). We recognize, however, that the stated 5:1 ratio is prob-
lomatic for the specific deep epithelial model because this ratio
is more typical of the upper parts of such deposits (Hedenquist et al.
2000).

Santos et al. (2001) classify the deposits as Korean-type. We do
not deny the possibility of occurrence of such deposit types in the
region, as otherwise originally proposed by Robert (1996). Both
types, Korean and epithelial, can occur together in the same re-

gion (Robert et al. 1997). We argue, however, that the Korean-type
classification does not apply to the Davi and Joel prospects because
adularia, which is consistently present in the prospects, is not
mentioned at all in connection with Korean-type deposits (e.g.,
Robert et al. 1997; So and Shelton 1987). This points to the
significance of identifying adularia, evidently along with other fea-
tures, for genetic classification of the prospects.

Thus, taking into account the above discussion on the geolog-
ical features, we see no reason to change our classification of the
Davi and Joel gold prospects. It is essentially based on field, tex-

tural and mineralogical evidence, which have been considered ap-

propriate for the characterization of epithelial deposits (White
and Hedenquist 1990).

As for some possible “missing features”, we adopt the view of
Cox et al. (1993), according to which the features of a given type of
deposit may not all be present in one single specimen of the group.
This is reinforced with particular reference to epithelial deposits
by Taylor (1995, p. 340) who states specifically that not all the
diagnostic features of the type are to be always found in a given
deposit. Of the diagnostic features cited by Taylor (1995), we were
able to distinguish in the Davi and Joel prospects appropriate
mineral assemblages, evidence of shallow emplacement, fluid in-
clusion data, and evidence of boiling (e.g., adularia), in addition to
hydrothermal breccias and open space fillings.

Finally, it should be mentioned that Santos et al. (2001) say that
only seven of the 140 primary gold deposits in the Tapajós province
are hosted by subvolcanic felsic igneous rocks and, although this is
a common ore host in epithelial systems, the subvolcanic rock-
hosted deposits lack all other characteristics of epithelial deposits.
It may well be the case for the deposits specifically considered by
Santos et al. (2001), but, despite this, the geological environment is
anyway permissive for epithelial gold, as we indicated by our

classification of the Davi and Joel prospects. A confirmation of this
is the recent discovery of both high- (alunite-bearing) and low-

sulfidation (adularia-sericite) epithelial systems in the Tapajós
region, as reported by Jacobi (1998), Lestra (1999), Nunes et al.
These are located in volcanic rock-covered areas along the northern
part of the Tapajós province, the same areas where Santos et al.
(2001) say epithelial deposits do not exist. These discoveries
probably represent the situation where the erosion levels were
locally adequate for the preservation and exposure of entire
epithelial systems.

In our view, the geological setting is the most important aspect
for deposit classification. The (felsic) intrusive-volcanic setting of
the Tapajós domain is permissive for epithelial gold deposits, and
the preservation, at least in part of the region, of host rocks typi-

cally associated with these shallowly formed ore deposits allows for
the preservation of the deposits themselves. The epithelial model
was originally proposed by us for the Joel and Davi prospects and
since then it has been shown to be applicable elsewhere in the
province by the many new discoveries.

References
Bastos Leal LR, Tassara CCG (1994) Características das miner-

alizações auríferas fisionóis dos gerais do Crepótorzinho e Crepóto-

rizão, Província Aurífera do Tapajós, PA. XXXVIII Congresso Brasileiro Geologia. Anais 1:285-286

Singer DA (eds) Mineral deposit models. US Geol Surv Bull

1693:1-10

Dreher AM, Vlach SRF, Martini SL (1998) Adularia associated
with epithelial gold veins in the Tapajós Mineral Province,
Pará State, northern Brazil. Rev Brasil Geociências 28(3):397-404

for epithelial gold. In: Hagemann SG, Brown PE (eds) Gold in


Jackson JA (1997) Glossary of geology. American Geological In-
stitute, Alexandria, Virginia

Jacobi P (1998) The discovery of epithelial Au–Cu–Mo Proter-

zoic deposits in the Tapajós Province, Brazil. Rev Brasil Geo-

ciências 29(2):277-279

Juliáni C, Nunes CMD, Bettencourt JS, Silva RHC, Monteiro

Proterozoic volcanic-hosted quartz-alumite epithelial deposits
in the Tapajós Gold province, Amazonian Craton, Brazil. Geol

Soc Am Abstr Programs 32(7):A-49

Lestra A (1999) Novos conceitos sobre a geologia e prospectão
de ouro no Tapajós. VI Simpósio de Geologia da Amazônia,
Ex-

tended Abstracts 65

Martini SL, Dreher AM (1996) Visita aos gerais Batalha e do

Davi: dados geológicos e petrográficos. CPRM. Proyecto Pro-

vícia Mineral del Tapajós. Relatorio Interno

Nunes CMD (2001) Caracterização de um sistema epiterial high
sulfidation paleoproterozoic na Provincia Aurífera do Tapaj-

ós, Pará. Dissertação de Mestrado. Instituto de Geociências
da USP, São Paulo

Nunes CMD, Juliáni C, Silva RHC, Bettencourt JS, Jacobi P
(2000) Paleoproterozoic quartz-alumite gold mineralization

from Tapajós, Brazil. 31st International Geology Congress, Rio
de Janeiro, Brazil

gold–silver deposits. In: Roberts RG, Sheeham PA (eds) Ore
deposit models. Geol Assoc Can 3:31-47

Pastana JMN, Angélica RS, Borges MS (1994) Garimpo do Davi,
Província do Tapajós: um provável exemplo de mineralização
aurífera associada a gossan. XXXVIII Congresso Brasileiro de
Geologia. Anais 2:156-158

Robert F (1996) Tapajós gold project, Pará State, Brazil. Canada–

Brazil cooperation for sustainable development in the minerals