Deformational processes in formation of the Bellechasse-Timmins gold deposit, southern Québec Appalachians, Canada

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I. INTRODUCTION

The Bellechasse-Timmins (BT) gold deposit is located approximately 110 km southeast of Québec city, more precisely 7 km from the town of Saint-Magloire in the Bellechasse County, Québec (Fig. 1), and is part of the Bellechasse gold belt of the southern Québec Appalachians (Gauthier et al., 1987). It is the result of fractures filling and the formation of saddle reef and related structures during orogenic deformation coeval with hydrothermal fluids circualtion and mineralization, such as typified, for instance, by the Lachlan Fold Belt of Central Victoria in Australia (Cox et al., 1991; Windh J., 1995).

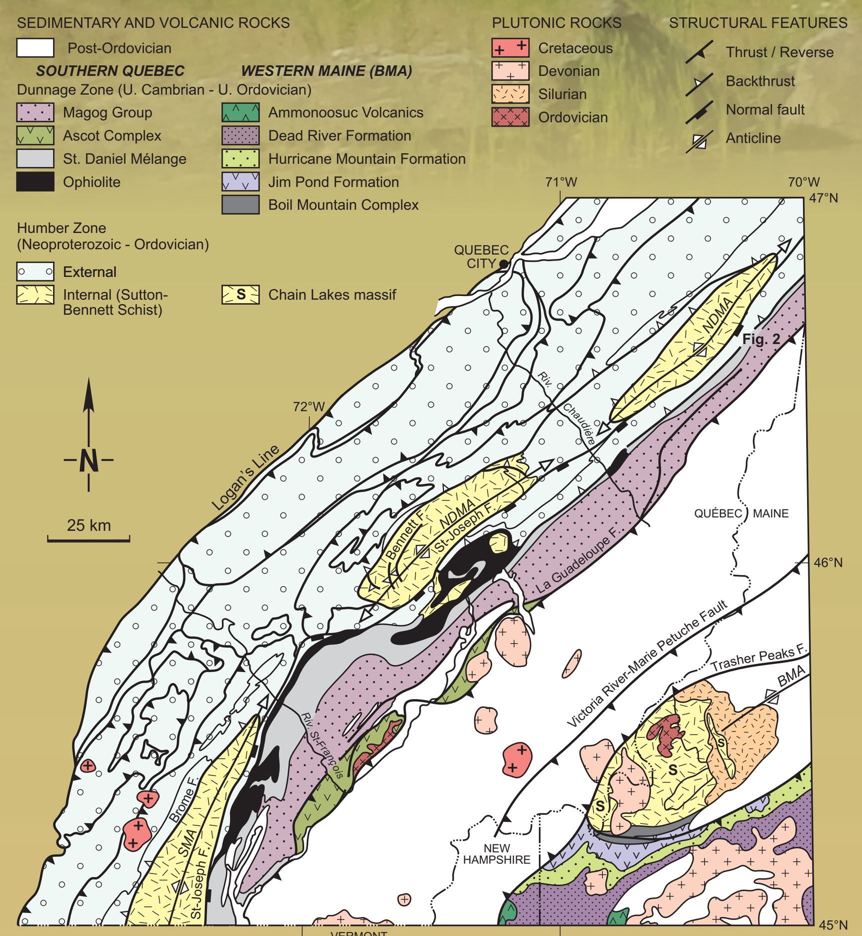


Figure 1: Geological map of the southern Québec Appalachians (De Souza, 2012).

II. REGIONAL GEOLOGY

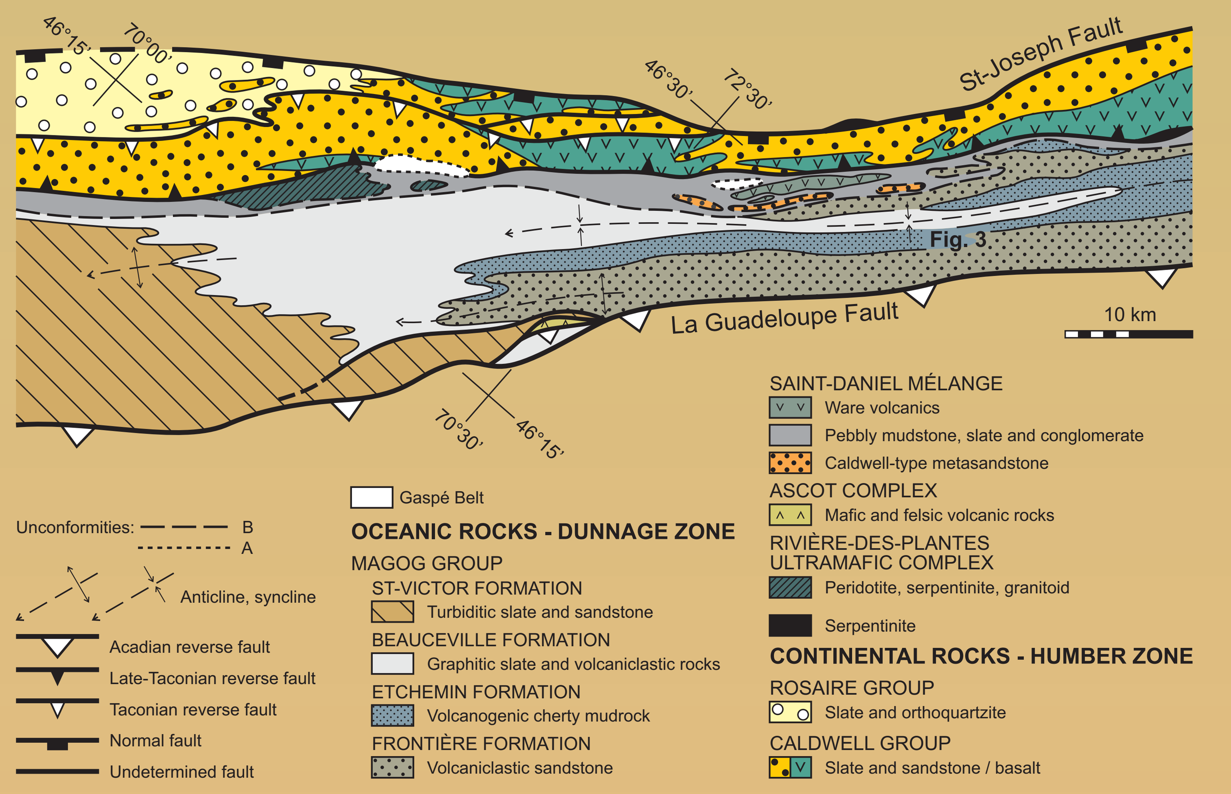
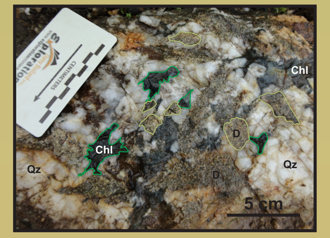


Figure 2: Geological map of the Beauce area showing the location of the Bellechasse-Timmins gold deposit (De Souza, 2012).

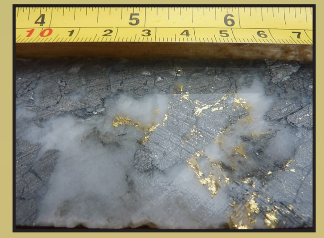
The BT gold deposit is hosted by the Magog Group, an Ordovician synorogenic forearc basin sequence belonging to the Dunnage Zone of the southern Québec Appalachians (Fig. 2). The Dunnage Zone is made up of ophiolites, island-arc volcanic rocks and synorogenic clastic and volcaniclastic sedimentary rocks related to the obduction of Iapetan oceanic crust (Pinet et Tremblay, 1995; Tremblay et al., 2011). The Au mineralization is developed in diorite sills (and dykes) crosscutting the Upper Ordovician (Caradocian) Etchemin Formation, which has been deformed and metamorphosed at greenschist facies during the Middle Devonian Acadian orogeny (Tremblay et al., 2000).

III. AU MINERALIZATION & HYDROTHERMAL ALTERATION

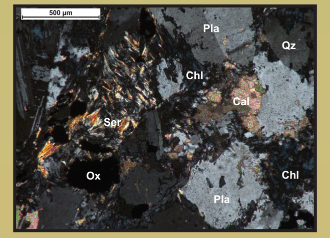
The Au mineralization consists of quartz veins and quartz-filled breccias (Photo #1), essentially developed in the diorite intrusions (Fig. 3), and which locally form well-developed stockwork structures. The veins are made up of quartz ± carbonates, minor sulphide minerals (mostly pyrite and pyrrhotite), and native gold occurences (Photo #2). Various types of mineral alteration are visible in the diorite, for instance, albitization, silicification, chloritization and carbonatization, all types being related to regional metamorphism (Photo #3).



Photograph 1: Quartz-filled breccias in the #1 Timmins zone.



Photograph 2: Drill core of #1 Timmins zone showing quartz vein with native gold.



Photograph 3: Thin section of a diorite showing the typical mineral assemblage of the regional greenschist -facies metamorphism (LPAx10).

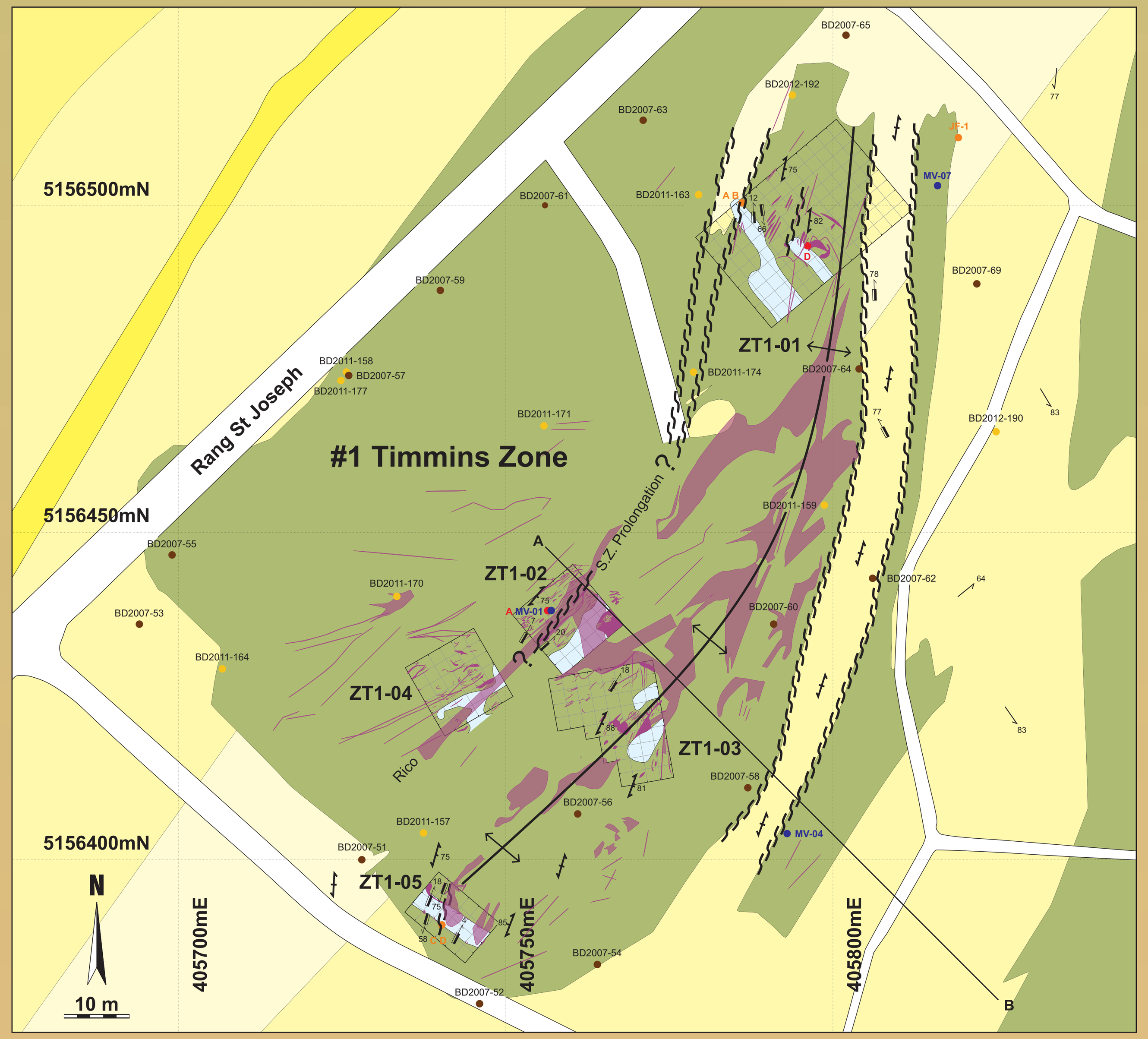
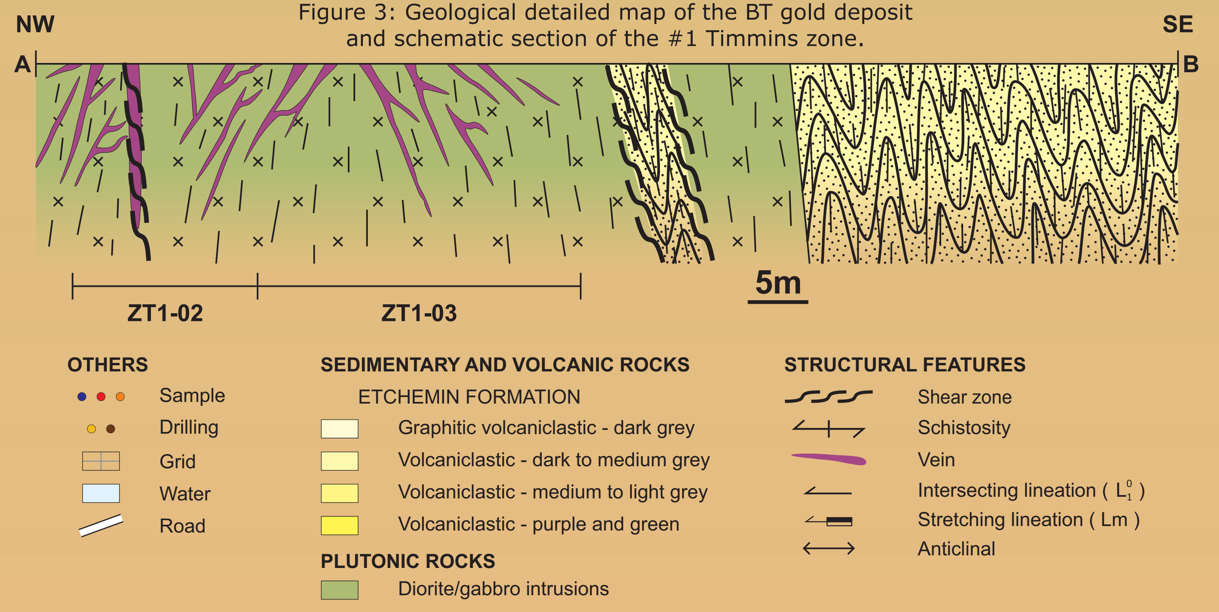
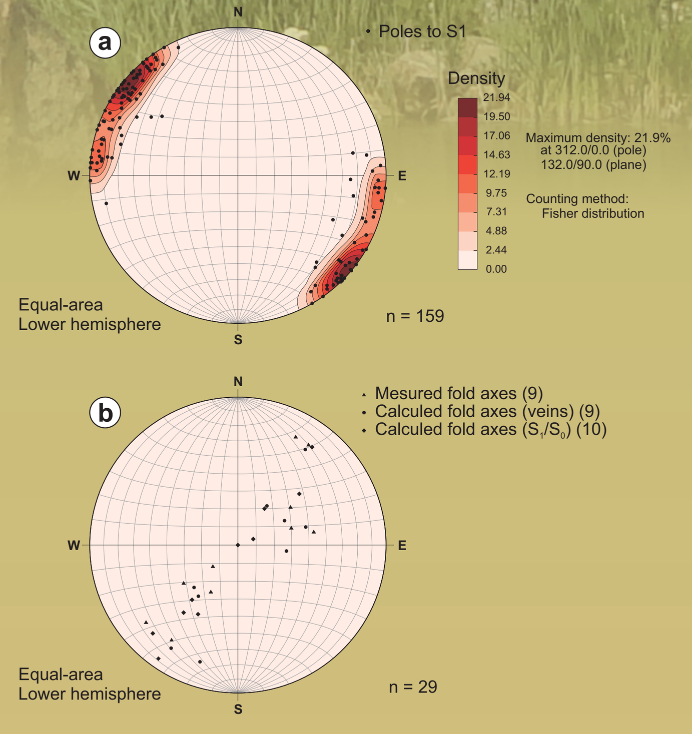


Figure 3: Geological detailed map of the BT gold deposit and schematic section of the #1 Timmins zone.

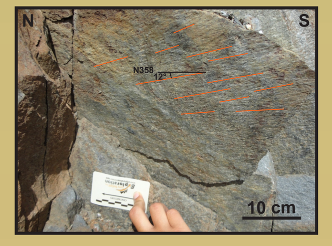


IV. STRUCTURAL CHARACTERISTICS



Figures 4a and 4b: Stereographic plots for S_1 and fold axes.

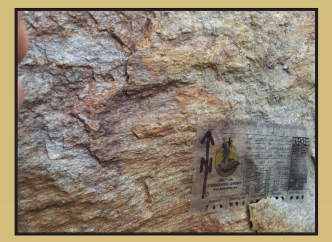
Our structural analysis shows that both the intrusions and hosting sedimentary rocks are crosscut by a steeply-dipping NE-trending axial-planar schistosity (Fig. 4a) and by 50 cm- to 5 metres-wide shear zones subparallel to that S_1 schistosity. The shear zones host steeply-plunging slickenlines/lineations and preserved structural evidence for NW-verging reverse faulting (Photos #4 and #5). Subhorizontal lineations/fault striae are also locally found, suggesting late-stage strike-slip motion (Photos #6 and #7). Structural relationships between the bedding (S_0) and S_1 in the sedimentary rocks indicate that the sedimentary strata hosting the diorite are tightly folded, with fold axes plunging moderately to steeply (ca. 60°) toward the NE or the SW (Fig. 4b). As a result of rheological contrast between the two rock types, similar folds are found in the sedimentary rock sequence whereas the diorite intrusions are characterized by concentric folds (Fig. 5).



Photograph 6: Field example of subhorizontal lineations in shear zone, grid #1, Timmins zone #1.

Photograph 4: Field example of steeply-plunging lineations in shear zone, grid #1, Timmins zone #1.

Photograph 5: Field example of slickenside showing reverse motion, grid #1, Timmins zone #1.



Photograph 7: Field example of slickenside showing strike-slip motion, grid #1, Timmins zone #1.

V. QUARTZ VEINS GEOMETRY

There are 3 principal orientations of quartz veins, almost perpendicular to each other, and their intersection is subparallel to the fold axis developed in the diorite intrusions. These 3 orientations likely represent different stages of deformation and veins formation (Fig. 4c). The first one, subparallel to S_1, was formed during the development of the schistosity. The second family, represented by flat-lying extension veins, is attributed to folding, when intrusions start to be fractured due to high competency contrast and during variations of hydrothermal fluid pressure. These veins are locally folded, which indicates that they were formed before the end of folding (Photos #8 and #9). Finally, the third type of veins is the result of fracturation during NE-SW extension and/or late-stage compressional strike-slip faulting coeval with the NW-directed compression that generated the auriferous shear zones.

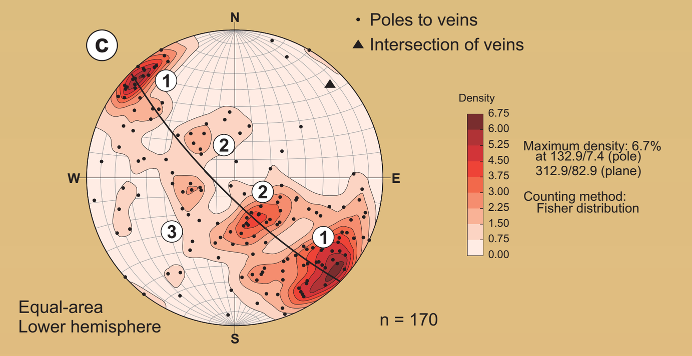


Figure 4c: Stereographic plots for veins.

Photograph 8: Folded extension veins, grid #2, Timmins zone #1.

Photograph 9: Field example of dilatation jog, grid #4, Timmins zone #1.

ACKNOWLEDGMENTS

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VI. DISCUSSION & CONCLUSION

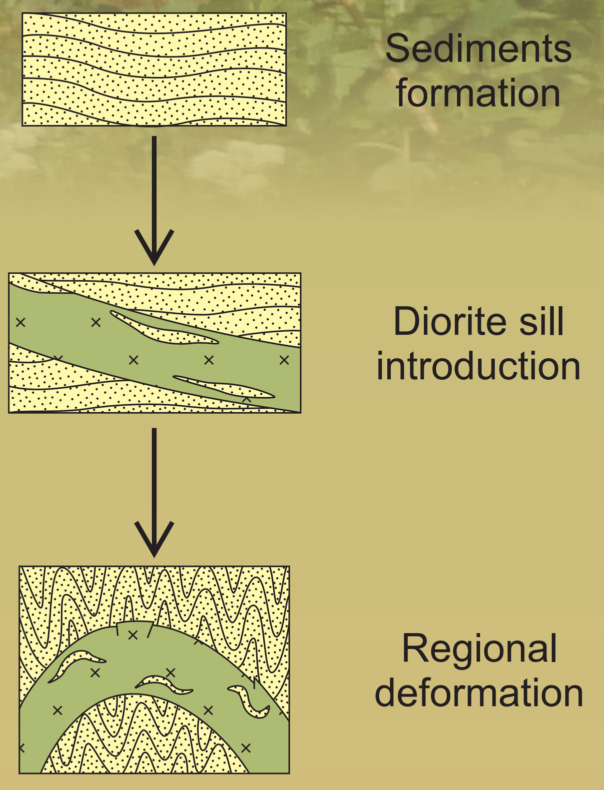

Figure 5: Schematic evolution for formation and deformation of the dioritic intrusions hosting the Au mineralization.

The occurrence of down-dip lineations indicates the predominance of reverse faulting during mineralization. Ductile-brittle shears related to the mineralization are mainly due to flattening and «locking up» of fold hinges, which have been sheared out by high-angle reverse faults (Fig. 6). The overall geometry of the ore zones is therefore controlled by and coeval with the regional folding event, and basically represents the product of hydrothermal circulation and fracturing related to regional metamorphism and folding affecting the diorite sills/dykes and hosting sedimentary rocks. Fluids migrated along faults/shear zones and other weakness planes (such as bedding and S_1) during folding and precipated in favourable low-pressure dilation zones (e.g. faults, S_1 planes, fold axes) created when the hydraulic pressure of trapped fluids exceeded the lithostatic pressure (Cox et al., 1991; Windh J., 1995).

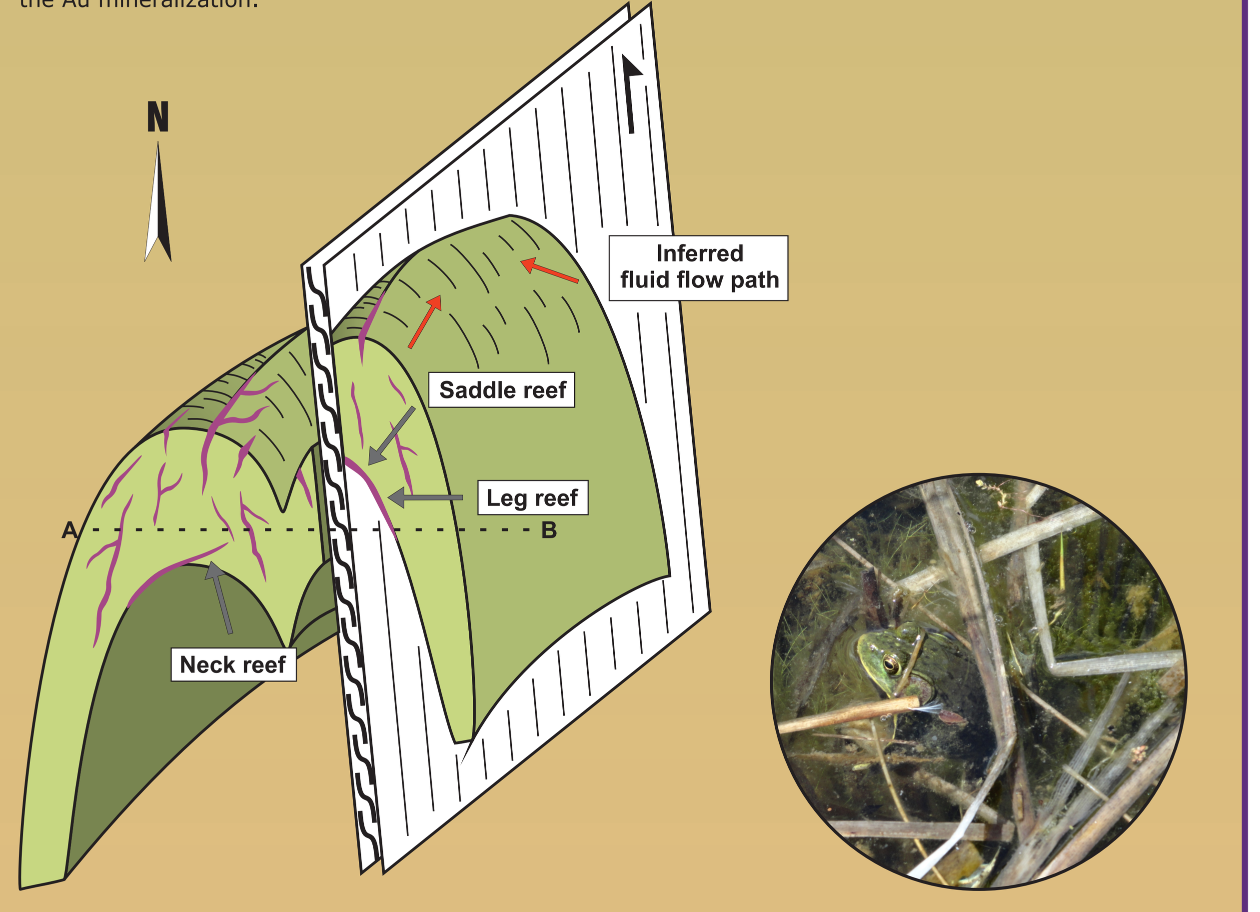

Figure 6: Schematic interpretation of the geometry of the BT gold deposit, as the result of fold-related saddle reef structural trap (3D).

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