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The gold quartz vein of Pontal, Tocantins, Brazil

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ABSTRACT: The Pontal deposit consists of an auriferous quartz vein hosted by tonalitic orthogneisses deformed by ductil shear and metamorphosed in the amphibolite facies. It is generally concordant with the mylonitic foliation of surrounding gneisses, presinting a tabular aspect and boudinaged structure. Its mineral assemblage consists of oligoclase, actinolite, biotite and less 2% sulfides (pyrrotite, pyrite, sphalerite, chalcopyrite and galena). Native gold occurs as disseminated particles in the quartz crystal interstices or sometimes filling fractures. Primary inclusions present in the quartz matrix are geometrically related to gold particles, and contain a H_2O-CH_4 fluid, daugther and trapped solids (graphite, siderite, dolomite, calcite, biotite, actinolite and rutile). Trapping temperature range from 300 to 420°C. The presence of graphite and carbonates lead to the supposition that gold deposition has occured in a reducing system at elevated temperature with boundary conditions between greenschist and amphibolite facies, related do decreases of oxygen fugacity and pH.

1 INTRODUCTION

The Pontal deposit is located in the Tocantins state, Brazil, at the latitude 10°52' and latitude 48°36' (figure 1).

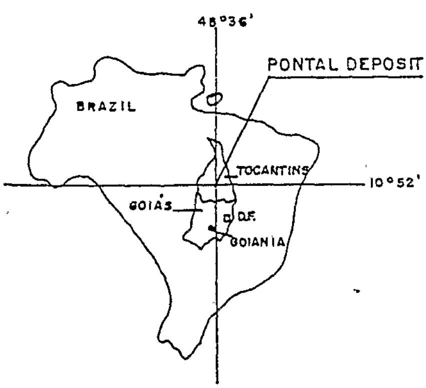

Fig. 1 Localization

Presently, 10,000 tons of auriferous quartz vein with an average grade of about 17,5 ppm Au have been mined by Metago.

The mineralization formed defore 1.8 b.y. and presumably during early Proterozoic times. It occured after the methamorphism of the host basement rocks to the amphibolite facies.

Petrological interpretation of the mineral association trapped in quartz as solid-inclusions as well as a study of its fluid inclusions (microthermometry and Raman analyses) have been done to establish the physico-chemical conditions prevailing during ore deposition.

2 REGIONAL GEOLOGY

Geophysical data (gravimetry and magnetometry) deduced a structural framework for Goiás and Tocantins states, linked through thrust zones in four crustal blocks named, Araguacema, Porangatu, Brasília and Paraná (Hasui et al., 1985; figure 2).

The Pontal deposit is hosted by archean gneisses of Goiás basement complex (figure 3) located at the northeastern part of Porangatu block which overthrust the Araguacema block and are overthrusted by the Brasília block. This block is intersected by regional lineaments with NNE strike (Transbrasilianos lineaments;Schobbenhaus, 1975) represented by faults and transcurrents ductil shear zones with isochronic Rb-Sr age about 2.0 b.y. (Costa et al.,1988).

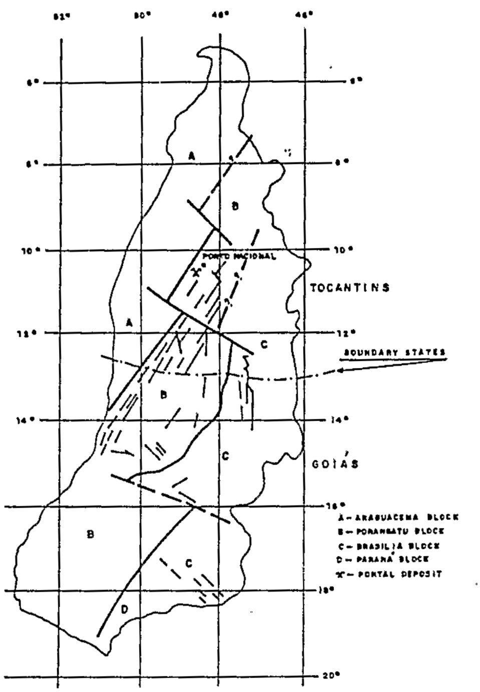

Fig. 2 Structural framework for Goiás and Tocantins states

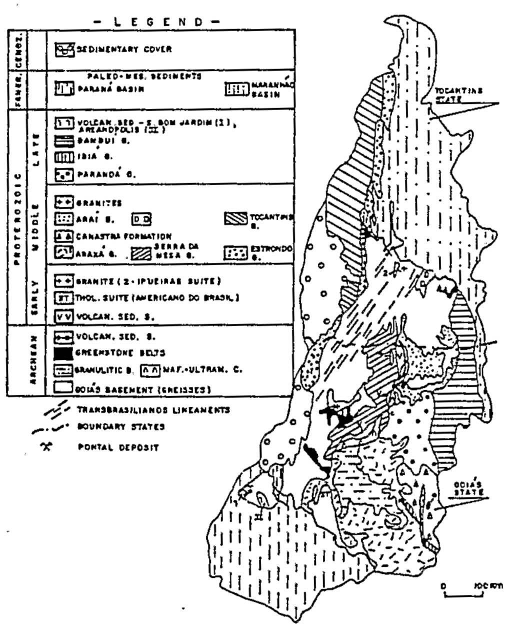

Fig. 3 Simplified geology of Goiás and Tocantins states

3 LOCAL GEOLOGY

The main lithologic unit exposed in the mine area consists of biotitic and biotite-hornblend orthogneisses with amphibolite intercalations. The observed mineral association in these rocks (oligoclase+quartz+biotite+hornblend+garnet) are diagnostic for metamorphic culmination in the amphibolite facies.The orthogneisses display a mylonitic foliation oriented N15-30E and dipping 60 to 70°SE.A subhorizontal stretching lineation defined by oriented biotite platelets and various deformation aspects as anastomosed foliation,rotacioned sigmoids, sheet folds and boudinage, suggests a transcurrent ductil deformation in a dextral simple shear regime.

Auriferous saccharoidal quartz veins white to dark grey coloured are usually parallel to the mylonitic gneisses foliation and sometimes cut it at low angle.They have variable length (centimetric do decametric) with macimum of 120m (Pontal deposit). Barren quartz veins, milk coloured and fine grained,cut either mylonitic gneisses or saccharoidal veins at high angle.

Later granitic intrusions(porfiritic biotite granite and fine biotite granite)contain xenolites of mylonitic gneisses and have related pegmatitic injections that cut both metamorphic basement and quartz veins. Porfiritic biotite granite belongs to Ipueiras suite and presents Rb-Sr isochronic age about 1,8 b.y.(Costa et al.,,1988).

Devonian detrital sediments of Pimenteiras Formation (rythimic alternation of ferruginous arenite, siltstone and argillite) overlay the basement and granitic rocks unconformably (figure 4).

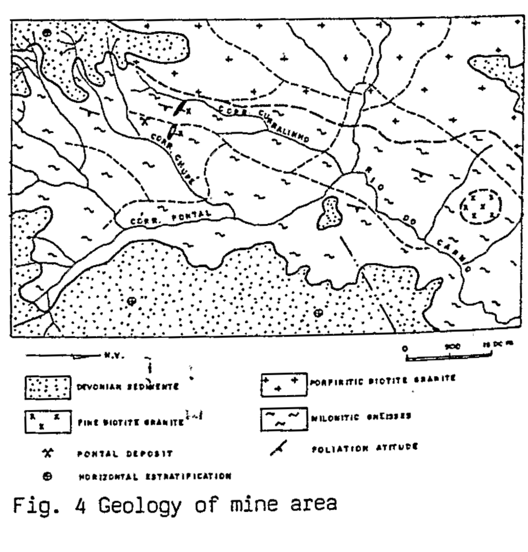

Fig. 4 Geology of mine area

4 MINERALIZATION CHARACTERISTICS

The auriferous quartz vein at the Pontal deposit presents a tabular aspect: 120m along strike, 0.5m overage thickness and 60 to 100m down dip. It is concordant with the mylonitic gneisses foliation (N15-30E, 60-70SE) and sometimes cuts it at a low angle. This lens Is boudinaged (centimetric to metric) parallel to the X axis of strain ellipsoid (figure 5).

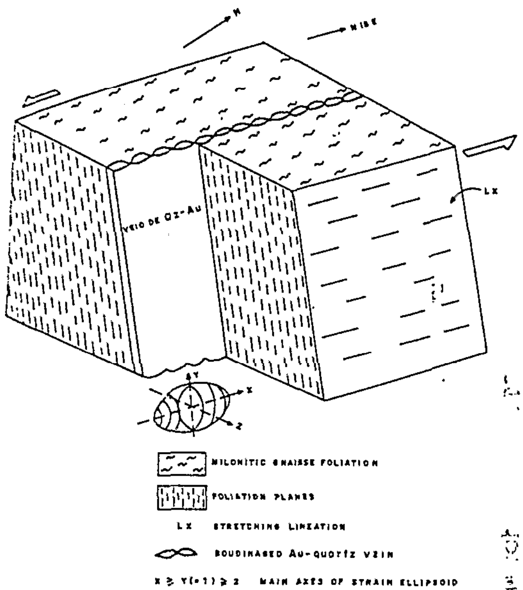

Fig. 5 Schematic diagram block of deformation at the mine area

Its mineralogical assemblage is dominantly composed of white do dark grey saccharoidal quartz (90%) showing ondulated extinction with indented and satured contats, The remainder are biotite (4%), oligoclase (3%), tremolite/actinolite (1%) and around 2% sulfides (55% pyrrotite, 28% pyrite, 9% sphaletire, 6% chalcopyrite and 1% galena). Microprobe investigation of quartz reveled solid inclusions of actinolite/tremolite, oligoclase and biotite.

Native gold occurs as irregular and euhedral disseminated particles in the quartz crystal interstices or sometimes filling fratures, with sizes spanning in the following fractions: 25% over +65 mesh 0.21mm), 22% over + 100 mesh (0,15mm), 29% over + 200 mesh (0.074mm), 9% over + 270 mesh (0.053mm) and 15% bellow + 270 mesh. Only 3% and 2% gold are associated with sulfides and silicates respectively.

5 FLUID INCLUSIONS STUDIES

5.1 Typology

Five main types of fluid inclusions have been defined from microscopical observations:

Type 1 - large sized(about 15 to 80 um)multiphase primary inclusions, with Low filling degree by the vapour phase (0.1 to 0.2). They are isolated within quartz grains and contain several solids with distinct shape, colour, refractive index and birrefringence (foto 1).

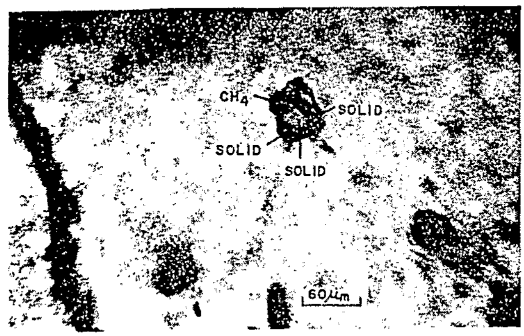

Foto 1 Type 1 multiphase flud inclusion

Type 2 - are medium sized(about 10 to 40 um) triphase (L+V+S) pseudo-secondary and/or secondary inclusions with a filling degree by the vapour phase of about 0.3 to 0.4. They form groups within a same crystal or trail cross-cutting boundaries of quartz grains (foto 2).

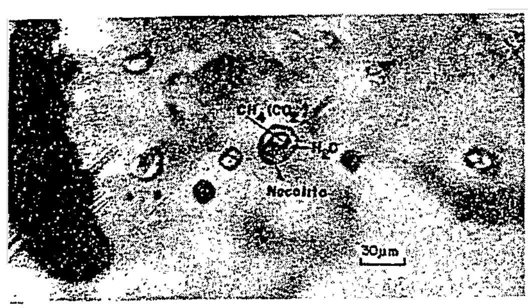

Foto 2 Type 2 triphase inclusion

Type 3 - are small to medium sized (about 3 to 40 um) two-phase (L+V) pseudo-secondary and/or secondary inclusions with a filling degree by the vapour phase of about

0.3 to 0.4. They form groups within a same crystal or trail cross-cutting boundaries of quartz grains (foto 3).

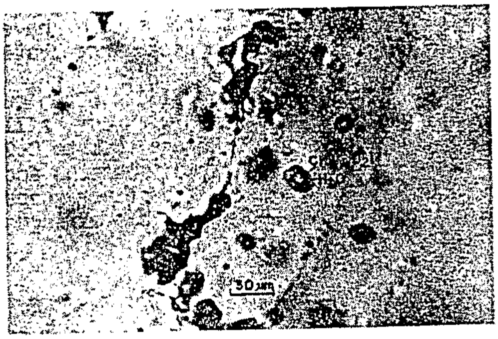

Foto 3 - Type 3 Two-phase pseudo-secondary and/or secondary inclusions

Type 4 - are small to medium sized (about 3 to 20 um) two-phase (L+V) primary inclusions with a filling degree by vapour of about 0.9. They appear scattered within the quartz crystals (foto 4).

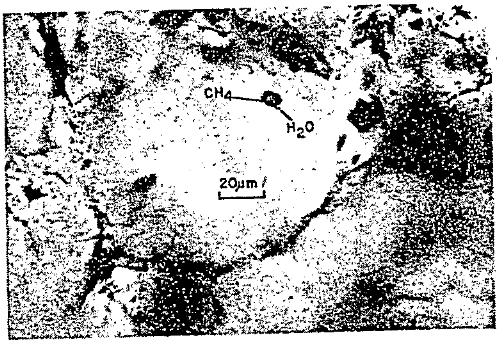

Foto 4 - Type 4 Two-phase primary inclusion

Type 5 - are small to large sized (about 3 to 50 um) two-phase (L+V) secondary inclusions of late origin, with a filling degree by vapour of about 0.1 (foto 5).

Foto 5 Type 5 two-phase secondary inclusions

5.2 Raman microprobe data

Raman spectra of gas and solids on the main type inclusions have been established using a U 1000 apparatus (Guilhaumou et al., 1989).

Type 1 - contain trapped biotite and amphibole comparable with spectra from same phases trapped as isolated large sized solids inclusions in the quartz matrix. Also trapped appears rutile with characteristics peaks at 448 and 610 cm^{-1} (figure 6).

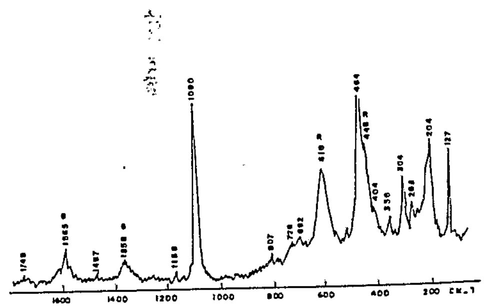

Fig. 6 Raman spectra of graphite and rutile

Daugther phases were determined as graphite-like grains indentified by two broad bands at about 1360 and 1590 cm^{-1} (figure 6), and rhomboedral carbonates represented by siderite, dolomite and calcite, as shown by characteristics peaks on Raman spectra (table 1). in vapour phase, mainly CH_4 has been detected and several percents of CO_2 (table 2).

Table 1. Raman spectra for carbonates

Reference	$2v_2$	vCO_3	v_4	L	T	Phases
N35110BIFC						
S1	1753	1094	722	295	170	dolomite
S2	1737	1091	733	300	192	siderite
N35110BIFA						
S1	1736	1809	735	302	196	siderite
N22AZIFA						
A35	1744	1091	735	105	193	siderite
N3580BIFD						
S1	--	1090	736	304	195	siderite
N3580BIFA	--	1092	730	306	197	siderite
N3580BIA						
S1	--	1092	736	306	193	siderite
N1101FA						
S1	--	1092	734	305	200	siderite
N156CA						
S1	--	1094	723	299	171	calcite
S2	--	1087	713	283	156	calcite

$2v_2$ - Out of plane bend
vCO_3 - Sumetric strech of CO in CO_3
v_4 - In plane bend
L - Libration mode
T - Translation mode

Table 2. Raman analyses for gas and solids

Incl. type	Solid phases				Gas phases			
	Car	Gr	Rut	Nah	CO_2	CH_4	N_2	CO_2/CH_4
1	+	+	+	-	81	19	-	4.26
1	+	+	+	-	82	18	-	4.55
1	+	+	+	-	0	100	-	
1	+	-	-	-	0	100	-	
1	+	+	+	-	0	100	-	
1	+	+	+	-	0	100	-	
2	-	-	-	+	0	100	-	
2	-	-	-	+	0	100	-	
2	-	-	-	+	0	100	-	
2	-	-	-	+	89	11	-	8.10
2	-	-	-	+	18	82	-	0.22
2	-	-	-	+	0	100	-	
3	-	-	-	-	0	100	-	
3	-	-	-	-	98	2	-	49.00
3	-	-	-	-	94	6	-	15.60
3	-	-	-	-	95	5	-	19.00
3	-	-	-	-	15	58	27	0.26
4	-	-	-	-	0	100	-	
4	-	-	-	-	0	100	-	
4	-	-	-	-	0	99	1	
4	-	-	-	-	0	100	-	
4	-	-	-	-	0	99	1	
4	-	-	-	-	0	90	10	

Car-carbonate; Gr-graphite; Rut-rutile; Nah-nahcolite. + present; - absent.

Type 2 - these inclusions host daugther crystals of nahcolite (foto 2) identified by the peaks 463 and 1044 cm^{-1} (figure 7). The gas phase contains usually higher CH_4 and lower CO_2 amounts (table 2).

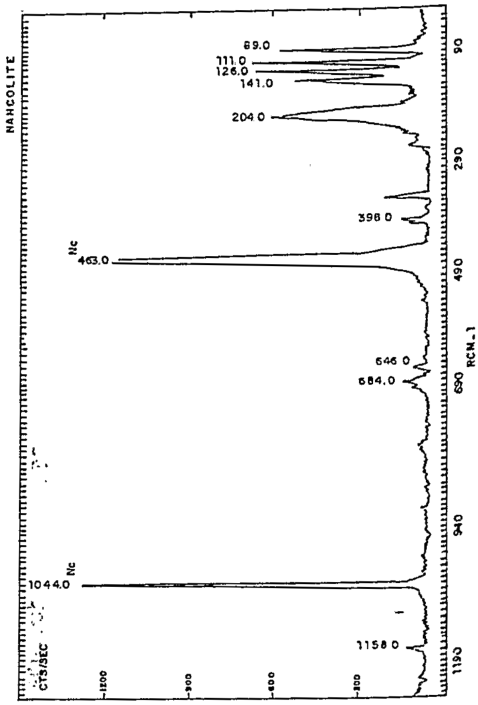

Fig. 7 Raman spectra of nahcolite

Type 3 - they contain vapour phases consisting mainly of CO_2 with minor CH_4 and N2 amounts (table 2).

Type 4 - the vapour phase consists essencialy of CH_4 with rare N_2 (table 2).

Type 5 - in don't contain any detectable volatile, only H_2O (L and V).

5.3 Microthermometry data

The microthermometry has been done using a Chaixmeca apparatus with capability of temperatures between - 180°C and + 600°C.

Type 1 inclusions presented homogenization temepratures or fluid phases spanning from 300 to 420°C (figure 8). Only inclusions containing dominant CO_2 displayed the homogenization temperature of CO_2 at-6°C. Some dissolution of carbonates was observed during several heating runs.

Type 2 inclusions showed the homogenization temperature scattering in the 260-500°C range (figure 8). Dissolution of nahcolite was observed around 180°C.

Type 3 inclusions displayed homogenization temperatures varying in the 200 - 400°C range (figure 8). The melting temperatures of CO_2 scattered from - 58 to about -70°C. The homogenization temperatures of the CO_2 phases were extremely variable, but occur predominantly between + 10°C and + 11°C. The last melting of ice in presence of clathrate occured between - 4 and - 7°C. The clathrate melting temperatures were observed between + 6 and + 16°C.

Type 4 inclusions displayed only homogenization temperatures in the vapour phase scattering in the 340-540°C range (figure 8).

Type 5 inclusions displayed homogenization temperatures in the liquid phase between 140 and 300°C (figure 8(, and the last melting temperature of ice in the - 2°C to - 5°C range.

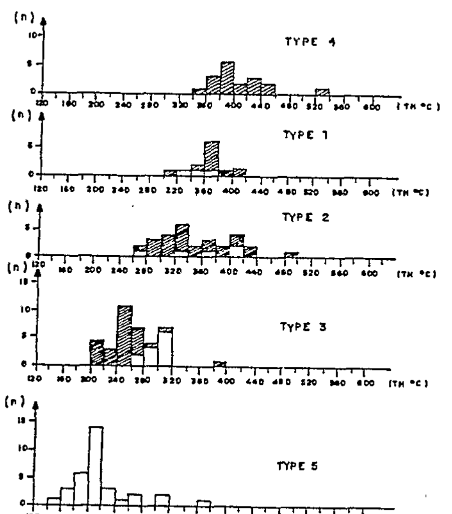

Fig. 8 Total homogenization temperatures of the main types fluid inclusions

6 CONCLUSIONS

In the auriferous quartz vein at the Pontal deposit the formation of type 1 inclusions synchroneous with the trapping of oligoclase, actinolite/tremolite, biotite and native gold (solid inclusions in quartz), suggest a primary origin of these inclusions. Type 2 and 3 fluid inclusions represent early circulations of secondary fluids with variable CO_2/Ch_4 ratios (table 2). Type 4 inclusions represent high temperature and low density methane rich fluids, sometimes geometrically related do gold particles, although no convincing evidence supports the hypothesis of coeval type 1 and type 4 inclusions. Type 5 fluid inclusions correspond to late hydrothermal aqueous solutions.

From petrographic arguments, the trapping of type 1 multiphase and of the solid inclusions in quartz (including gold) occured under the T-P conditions prevailing at the boundary between the greenschist and the amphibolite facies (biotite + actinolite + oligoclase stable). Referring to several authorities (Winkler, 1979; Turner and Verhoogen, 1960), T may be estimated to about 500-550°C, P being more difficult to constrain. However, type 1 inclusions with homogenization temperature of CO_2 at -6° C can define the molar volume at about 50cm³/mol when the CH_4 content is around 20% Heyen et al., 1982). Using this value for formation temperatures (300-420°C and 500-550°C, the pressure can be estimated between 2 and 3 Kb, respectivelly (Holloway, 1981; figure 9).

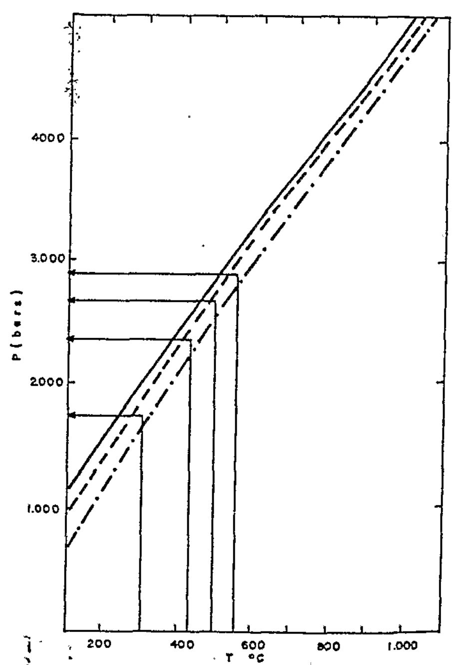

Fig. 9 Isochores of CH_4(full line), CH_4-CO_2 (dashed line) and CO_2 (dashed Line-dot) for 50cm³/mol

Most of type 1 fluid inclusions contain only detectable methane as a volatile component, but some inclusions (table 2) are dominated by CO_2. At 500°C, with the ratio CO_2/CH_4 = 4 and in equilibrium with graphite, fO_2 plots slihtly over the QFM buffer, for the estimated pressure (Kreulen,1987; point A in figure 10). Although for inclusions without detectable CO_2, fO_2 is evidently lower but cannot be estimated, the plots were made for CO_2/CH_4 = 1/99 (point B in figure 10). These variations of fO_2 at the tome of primary fluid incluid inclusions trapping, resulting from precipitation of the graphite phase (Dubessy, 1984), may have triggered gold precipitation through destabilization of Au $(HS)_2^-$ complex (Touray, 1987; Shenbergert et al., 1989).

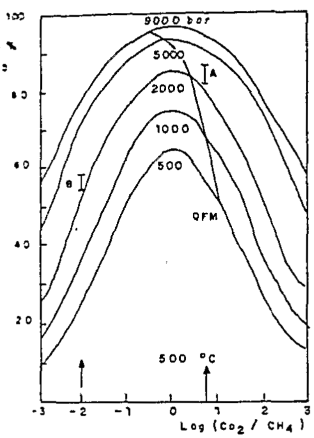

Fig. 10 Relation between log (CO_2/CH_4) and mol % H_2O in graphite buffered fluids

Finally, the Pontal auriferous quartz vein may described as high temperature metamorphogenic deposit (Movarek et al.,1987), formed under variable oxygen fugacity,with redox conditions ranging from QFM buffer to lower values. A major unsolved problem is the origin of the carbon-bearing fluids: because the usual assumption of a source from graphitic shales may hardly be invoked, in view of the lacking of such sediments in the basement,some deep crustal (or mantle) source appears more probable.

Similarly, the classical hypothesis of a gold source within local ultrabasic rocks seems unlikely, and some deep source has to be invoked.

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