GEOCHRONOLOGY AND ISOTOPE GEOCHEMISTRY OF THE MAFIC DIKES FROM THE VAZANTE GROUP, BRAZIL: IMPLICATIONS FOR THE TIMING OF THE Zn-(Pb) MINERALIZATION

Babinski, M.[1]; Fetter, A.H.[2]; Monteiro, L.V.S.[3]; Bettencourt, J.S.[1] and Oliveira, T.F.[4]

1. Centro de Pesquisas Geocronológicas, Instituto de Geociências, Universidade de São Paulo, Rua do Lago562, São Paulo-SP, 05508-080, Brazil. babinski@usp.br, jsbetten@usp.br
2. Instituto de Geociências e Ciências Exatas, Universidade Estadual Paulista - UNESP, Av. 24 A, ñ 1515, CEP 13506-900, Rio Claro, SP, Brazil. fetter@ms.rc.unesp.br
3. Instituto de Geociências, Universidade Estadual de Campinas - UNICAMP, R. João Pandiá Calógeras, 51 13083-970, Campinas-SP, Brazil - Fax 19 32891097. lenavsm@zipmail.com.br
4. Companhia Mineira de Metais Vazante, Caixa Postal 03, 38780-000, Vazante-MG. flavio@vz.cmm.com.br

Keywords: Vazante Group, ore deposits, geochronology, stable isotopes

INTRODUCTION

The Vazante Group (Dardenne et al., 1998), which occurs in the northwest part of Minas Gerais State, hosts the most important zinc non-sulfide (Vazante) and sulfide (Morro Agudo) deposits known in Brazil. This group represents one of the metasedimentary units of the southern segment of the Brasília Fold Belt, which extends for more than 1000 km over a width of 300 Km along the western margin of the São Francisco Craton (Fig. 1).

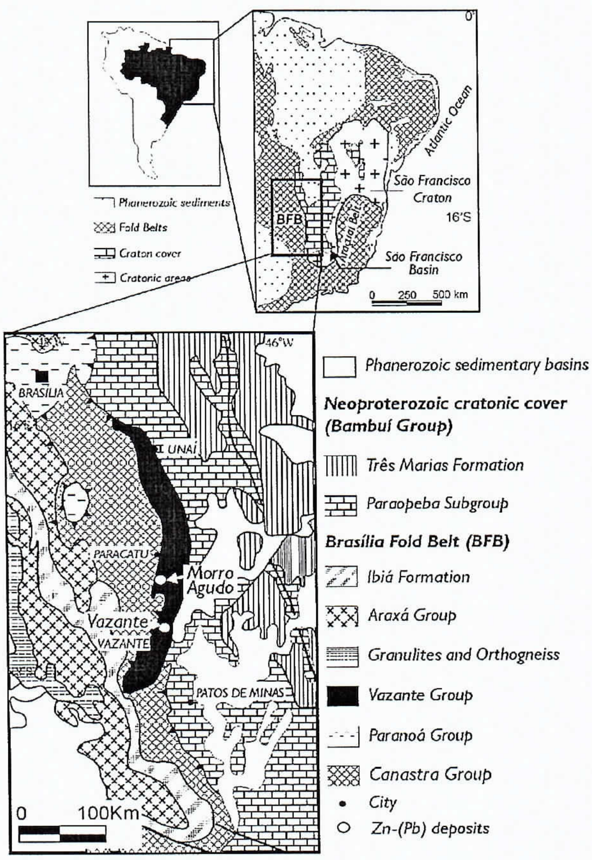

Figure 1. Geological map of the southern part of the Brasília Fold Belt (Dardenne, 2000).

The tectonic setting of this unit, however, is controversial. Recent studies indicate that the Vazante Group could represent the sedimentation in a rapidly subsiding zone forming a depression in the Brasília Fold Belt initial thrust fronts (Dardenne, 2000), in a similar setting to that of the Bambuí Group, or might correspond to top of the meso/neoproterozoic passive margin sequence, represented mainly by the Paranoá Group (Pimentel et al., 2001).

The Vazante Group is composed by a thick sedimentary sequence and its depositional age is still disputable. The available geochronological data do not give reliable constraints on the depositional age of the sequence, but indicate that it was metamorphosed during the Brasiliano Orogeny (Amaral & Kawashita, 1967). Recently, however, metamorphosed basic dikes cutting the sedimentary sequence were found and their geologic relationship showed promise for constraining the minimum depositional age of the sediments and timing of the mineralization event. Here we present U-Pb, Pb-Pb, and Sm-Nd isotopic data obtained from these mafic dikes, along with petrological, geochemical and C, O and Sr isotopic studies.

GEOLOGICAL SETTING

The Vazante Group is composed, from base to top, of metapelitic units with phosphorite occurrences (Retiro and Rocinha Formations), metapsamo-pelitic units and stromatolitic bioherm facies (Lagamar Formation), gray slates (Serra do Garrote Formation), dolomite, slates, sericite phyllite and marls (Serra do Poço Verde Formation), stromatolitic bioherm facies (Morro do Calcário Formation), carbonaceous slate, phyllite, dolomite and quartzite lenses (Lapa Formation) (Dardenne, 2000).

Minor magmatism associated with the Vazante Group is represented by small bodies of metabasic rocks, identified mainly at the Vazante zinc mine (Fig. 2). In this deposit, the metabasic rocks (Fig. 2) occur, within the Vazante Shear Zone, tectonically imbricated with hydraulic breccias, hydrothermally altered rocks, and with zinc ore, composed mainly of willemite (Zn_2SiO_4).

This lithotype was described initially as diabase dikes of Cretaceous age (Rigobello et al., 1988). However, the presence of a metamorphic mineral assemblage (described below), and mylonitic fabric, which is not recognized in the Brazilian cretaceous rocks, are features that indicate that this unit was affected by the regional Brasiliano deformation event (Monteiro, 1997).

The metabasites and ore bodies are off-set by normal and reverse faults and also cut by late hydrothermal veins, which are likely to have caused complex relationships between ore bodies and the host sequence.

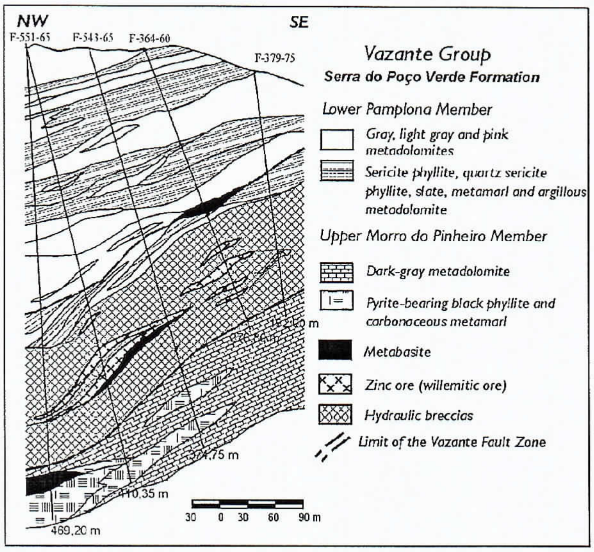

Figure 2. Cross – section of the Vazante ore zone showing the spatial relationship between metabasites, host sequence and the Vazante Fault Zone (simplified from Monteiro, 2002).

The metabasic rock exhibits relicts of sub-ophitic igneous texture and remnants of igneous minerals, such as plagioclase, pyroxene and ilmenite, which are replaced by a typical low greenschist facies assemblage. Sericite, clinozoizite, chlorite and carbonates replace plagioclase. Pyroxene exhibits strong chloritization, whereas ilmenite, initially zoned, is replaced by leucoxene, rutile and titanite (Fig. 3). Biotite remnants indicate early potassification, possibly preceding the mylonitization of this rock.

HYDROTHERMAL ALTERATION

Besides the low greenschist facies metamorphism, mylonitization and hydrothermal activity related to fluid flow within the Vazante Shear Zone also affected the metabasic rock. Chlorite (penninite), chrysotile and apatite formation, related to S-C structures, overprints the potassification. Late dolomitization associated with the formation of titanite, leucoxene, rutile and hematite, within brittle structures, accompany the total destruction of igneous textures and minerals.

Mass balance calculations (Monteiro, 1997) indicate that the mylonitized metabasite displays slightly mass increase (3%) relative to least-mylonitized metabasite. This mass increase is related mainly with MgO (~ 60%), CO_2 (~ 60%), Pb (~ 174%) e Zn (~ 212%) enrichments. Relative loss of Fe_2O_3 (~ 33%), Ba and Sr (~ 60%) are also observed.

The zinc ore, in tectonic contact with metabasic rocks, shows a different mineral association characterized by the Zn-rich chlorite, hematite, talc, and apatite.

Along the contact with metabasite, the dolomites are bleached and metasomatically altered and display also great differences in the isotopic compositions ($\delta^{18}O_{VSMOW}$= +21.4 to +16.7‰ and $\delta^{13}C$= -0.2 to -1.5‰) relative to unaltered dolomites ($\delta^{18}O_{VSMOW}$= +26.2 to +27.2‰ and $\delta^{13}C$ = -1.0 to +2.7‰).

The $^{87}Sr/^{86}Sr$ ratios of these bleached rocks ($^{87}Sr/^{86}Sr$= 0.732660) are also more radiogenic than the unaltered dolomites ($^{87}Sr/^{86}Sr$= 0.709239 to 0.709764) and the altered dolomites ($^{87}Sr/^{86}Sr$= 0.712948 to 0.715980) (Monteiro, 2002).

The calcite of this bleached metadolomite has the most distinct $\delta^{13}C$ value (-10.3‰), in relation to the hydrothermal carbonates within the fault zone ($\delta^{13}C$= -5.9 to +1.7‰) (Monteiro et al., 1999).

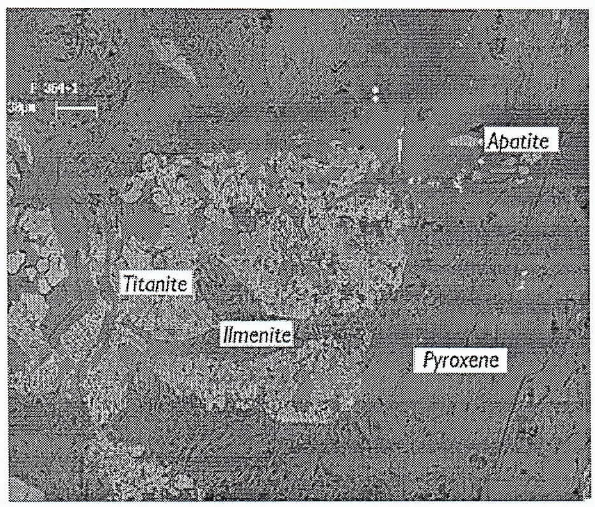

Figura 3. Back-scattered SEM image, showing the formation of titanite, which replaces igneous euhedral ilmenite.

RELATIONSHIPS BETWEEN THE METABASITE AND ZINC ORE

The metabasic rocks occur mainly within the Vazante Shear Zone, juxtaposed to dolomites and slates of the Vazante Group. This makes the recognition of the relationship between this metabasite and the host sequence difficult. However, there is evidence that this rock was affected by hydrothermal processes similar to those responsible by the zinc ore formation, which is coeval with the Vazante Shear Zone development (Monteiro, 1997; Monteiro et al., 1999).

Mass balance calculations and stable isotopic studies (Monteiro, 1997; Monteiro et al., 1999) indicate that the Zn- and Pb-rich fluids affected the metabasic rocks. Metasomatic processes affected metabasite, dolomites and zinc ore, indicating also strong fluid-rock interaction along the tectonic contact zones.

GEOCHRONOLOGY

Samples of the metamorphosed mafic dikes were recovered from drill cores. Three whole rock samples were powdered and Sm-Nd isotopic analyses were carried out. The T_{DM} model ages are between 1.16 to 1.21 Ga, and the $E_{Nd(0)}$ varies from +0.16 to –0.41. Because the Sm/Nd ratios are very fractionated (0.16) these T_{DM} ages are overestimated and represent the maximum crystallization age of the dikes. In addition, crustal contamination during magma ascent, which could increase the T_{DM} ages, cannot be ruled out.

Zircon and titanite grains were separated from two different cores.

The samples were crushed, sieved, and the <100 mesh heavy mineral fraction was concentrated. Sample VZ-1 yielded a reasonable quantity of small pink clear zircons. Another sample (VZ-2) had very low yield of zircons (also small pink clear ones); however a great amount of titanite was recovered from this sample.

The titanite grains are creamy brown in color, have a sugary texture, and are opaque (due to their microcrystalline texture).

Five small zircon fractions with different morphologies (from euhedral to rounded grains) of sample VZ-1 were analyzed, and all of them are discordant (Fig. 4). The zircons yielded $^{207}Pb/^{206}Pb$ minimum ages ranging from 2096 to 2398 Ma; the oldest age was determined on euhedral acicular zircons. A single fraction of euhedral zircons was recovered from sample VZ-2 and it yielded a $^{207}Pb/^{206}Pb$ minimum age of 2092 Ma with a very large error. However, this age is similar to ages obtained from two fractions of sample VZ-1 (Fig. 4). The U-Pb ages determined on zircons recovered from the mafic dikes are too old and indicate that the zircons were assimilated by the magma from the basement rocks. Although the results show some scatter on the U-Pb diagram, some fractions define a discordia that yields an upper intercept age of 2100 ± 25 Ma indicating the presence of a Paleoproterozoic basement for the Vazante Group. Furthermore, because of the older $^{207}Pb/^{206}Pb$ ages determined on some fractions, we can suggest that either the magma passed through crust composed of magmatic rocks older than 2.1 Ga or that metassedimentary rocks containing zircons from different sources are part of the basement in the area.

Seven single-crystal fractions of titanite were analyzed. Surprisinly, all the samples contained only common non-radiogenic Pb. The isotopic ratios are uniform and do not present a large variation. The $^{206}Pb/^{204}Pb$ values range from 17.68 to 17.92, $^{207}Pb/^{204}Pb$ from 15.60 to 15.70, and $^{208}Pb/^{204}Pb$ from 36.90 to 37.19, and most of them have large errors. The obtained results are in agreement with Pb isotopic ratios reported for galenas from the Pb-Zn deposits of Morro Agudo, Vazante, Ambrósia e Fagundes (Cunha et al., 2002; 2003) indicating that hydrothermal fluids responsible for the mineralizations might have affected the metabasic rocks. In addition, the presence of common Pb in the titanite, which typically has high U/Pb ratio, confirms the petrographic observations that this mineral is hydrothermal and it is coeval with the timing of Pb-rich fluid percolation.

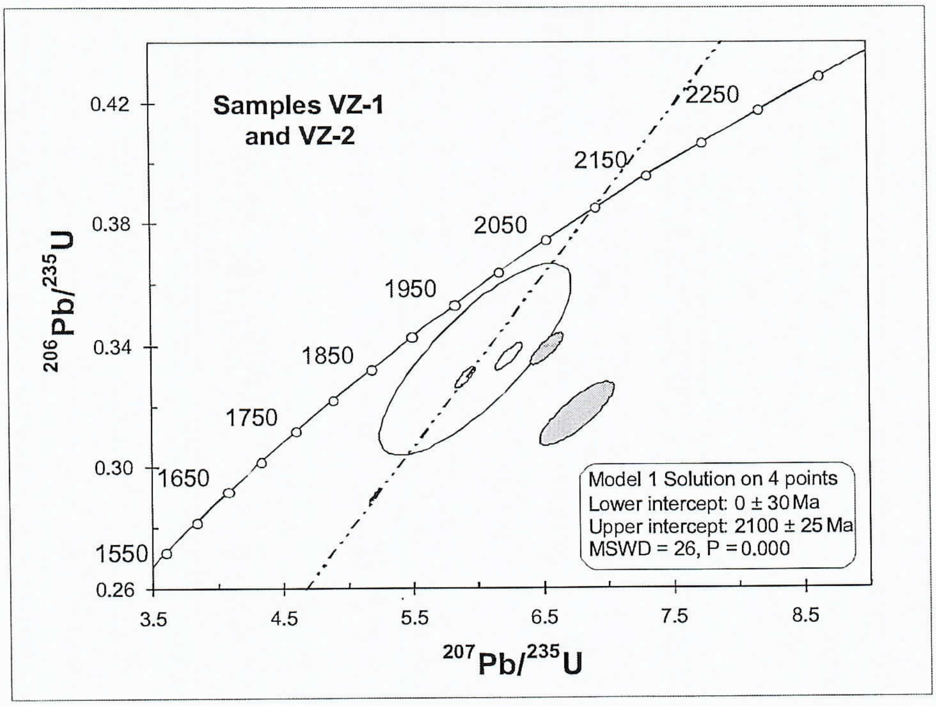

Figure 4. U-Pb concordia diagram of zircons from metabasites from the Vazante Formation. The analyses represented by filled ellipses were not used for regression. The analysis with higher error is from sample VZ-2; all the other points were obtainedfrom zircon fractions separated from sample VZ-1.

CONCLUSIONS

The metabasite was affected by epigenetic-hydrothermal processes similar to those responsible for the Vazante zinc non-sulfide mineralization, which is closely linked to the Vazante Shear Zone development. The similar Pb isotopic composition of hydrothermal titanite from this metabasite and galena from the others zinc sulfide deposits hosted by the Vazante Group, could reinforce the importance of epigenetic-hydrothermal processes associated with the late Brasiliano event for the genesis of the zinc deposits in the Vazante-Paracatu Zn – (Pb) district.

ACKNOWLEDGMENTS

We are grateful to Companhia Mineira de Metais for continuous support and hospitality at the mine. This research was partially supported by PRONEX funds (Project 167/96), and FAPESP grants (Proc. 98/0412-3 and 95/4652-2).

REFERENCES

Amaral, G. & Kawashita, K., 1967. Determinação da idade do Grupo Bambuí pelo método Rb/Sr. In: Congr. Bras. Geol., 21., Anais, SBG, p.214-217.

Cunha, I.A., Babinski, M, and Misi, A., 2002. Isótopos de Pb em galenas dos depósitos de Pb-Zn da região de Vazante-Paracatu: Dados preliminares. In: Congr. Bras. Geol., 41, Anais, SBG, p. 492

Cunha, I.A., Babinski, M, and Misi, A., 2003. Lead isotope study of galenas from the Vazante Group, Minas Gerais, Brazil. This volume.

Dardenne, M.A., 2000. The Brasília Fold Belt. In: Cordani, U.G.; Thomaz Filho, A.; Campos, D.A. (eds) Tectonic evolution of South America, Rio de Janeiro, Intern. Geol. Congr., 31st, p. 231-263.

Dardenne, M.A.; Freitas-Silva, F.H.; Souza, J.C.F.; Campos, J.E.G., 1998. Evolução tectono-sedimentar do Grupo Vazante no contexto da Faixa de Dobramentos Brasília. In: Congr. Bras. Geol., 40., Belo Horizonte, 1998., Resumos, SBG, p. 26.

Monteiro, L.V.S., 1997. Contribuição à gênese das mineralizações de zinco da Mina de Vazante, MG. Master Thesis, IGc-USP, 159 p.il.

Monteiro, L.V.S. 2002. Modelamento metalogenético dos depósitos de zinco de Vazante, Fagundes e Ambrósia, associados ao Grupo Vazante, Minas Gerais. Doctorate Thesis, IGc-USP, 317 p. il.

Monteiro, L.V.S.; Bettencourt, J.S.; Spiro, B; Graça, R.; Oliveira, T.F., 1999. The Vazante Zinc Mine, MG, Brazil: Constraints on Fluid Evolution and Willemitic Mineralization. Explor. Mining Geol., 8: 21-42.

Pimentel, M.M.; Dardenne, M.A;, Fuck, R.A.; Viana, M.G.; Junges, S.L; Fischel, D.P.; Seer, H.J.; Dantas, E.L., 2001. Nd isotopes and the provenance of detrital sediments of the Neoproterozoic Brasília Belt, central Brazil. J. South Am. Earth Sci., 14: 571 – 585.

Rigobello, A.E.; Branquinho, J.A.; Dantas, M.G. da S.; Oliveira, T.F.; Neves Filho, W., 1988. Mina de Zinco de Vazante. In: Schobbenhaus, C. & Coelho, C. E.S. (coords). Principais depósitos minerais do Brasil. DNPM, v.3, p. 101-110.