Magmatic Epidote, Hornblende Barometric Estimates, and Emplacement of the Conceiçào das Creoulas Pluton, Alto Pajeu Terrane, NE Brazil

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ABSTRACT

The Brasiliano-age magmatic epidote-bearing Conceiçào das Creoulas batholith, in the Transversal Zone superterranne in northeastern Brazil, intruded migmatites and metagranitoids of the Rio do Forno/Recanto Formations. This pluton is composed of porphyritic granodiorite and porphyritic monzogranite. Hornblendes in this pluton solidified between 6-7 kbar in mafic enclaves and around 8 kbar for porphyritic granodiorite as estimated by its Al contents. Temperatures for zircon saturation are in the 790-830°C range for the mafic enclaves and 800-850°C for the porphyritic granodiorite, whereas hornblende-plagioclase pairs yielded temperatures in the 670-690°C range. In this pluton, epidote, undoubtedly of magmatic origin, with or without allanite cores, included in plagioclase, is rimmed by biotite or is partially resorbed by the magma. Sometimes, patches of hornblende and biotite are present inside epidote. Magmatic epidote compositions vary in the interval 20-25% mole of pistacite, and always exhibit TiO₂ < 0.20% by weight. This compositional range suggests crystallization along the NNO buffer. High ⁸⁷Sr/⁸⁶Sr initial ratio suggests a significant crustal component in the magma genesis. The magma probably was transported upward by diking and inflated outwards near at its final site of emplacement, giving to the pluton a diapiric appearance.

Key words: magmatic epidote, calc-alkaline, barometry, emplacement.

INTRODUCTION

Although magmatic epidote (mEp) was identified in the beginning of the present century (Cornelius, 1915), its petrogenetic significance as a distinctive geobarometric indicator was only demonstrated by Naney (1983) and Zen & Hammarstrom (1984). After the initial debate on the existence of epidote as a magmatic phase, mEp has now been widely accepted as a reliable tool for pressure estimates of magmatic crystallization. The effect of changes in physiochemical conditions during the extended crystallization range of mEp (early to late magmatic), preserved as inherent geochemical variations, can be successively employed to trace the ascent and emplacement process of the given granitoid body. The present paper aims (a) to model the ascent and emplacement mechanism; and (b) to deduce the crystallization history of the Conceiçào das Creoulas batholith.
(CCB) in the Alto Pajeú terrane, Pernambuco State, NE Brazil. The barometric estimates, based upon the epidote chemistry, are further substantiated by the hornblende chemistry. Empirical hornblende + plagioclase chemistry has also been utilized for thermometric deductions.

**LOCATION, GEOLOGY AND AGE**

The Conceição das Creoulas batholith is situated along the southwestern margin of the NE-SW trending, Alto Pajeú terrane in the Borborema province of NE Brazil (Fig. 1). The pluton, covering >120 km$^2$ (Fig. 2), has an elliptical outcrop pattern and almost flat top. The ENE trending major axis of the pluton is discordant with the NE-SW regional tectonic fabric of the Alto Pajeú terrane.

This pluton intruded the Early to Middle Proterozoic granite-migmatite basement represented by the Riacho do Forno/Recanto Formations (Santos, 1995). The intrusive relationship is also manifested in profound modification of the regional foliation in the country rocks. The outward dips of foliation in the country rocks, along the contact with the pluton, can be attributed to forceful emplacement of highly viscous melt. The well-preserved magmatic fabric, defined by biotite orientation, of CCB and absence of deformation induced planar features are distinctive of its late to post-orogenic emplacement. Crude foliation, developed along the margins of the pluton, appears to be a magmatic phenomenon, commonly associated with the emplacement of highly viscous, felsic melts.

This batholith predominantly comprises porphyritic biotite granodiorite and volumetrically insignificant (<10% volume), porphyritic biotite granite, which is restricted to the western fringe of the pluton. The biotite granite, occurring as dis-

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**Fig. 1 — Distribution of the main granitic plutons in the Transverse zone superterrane, northeast Brazil (from Sial et al., 1997).**

Fig. 2 — Geologic map of the Conceição das Creoulas batholith (modified from Santos, 1995).
seminated irregular patches, has chilled contacts with the biotite granodiorite. Both the granitoid types are characterized by randomly oriented, megacrystic K-feldspar (up to 10 cm long), as the main megacryst phase. The groundmass texture is usually medium to coarse grained, equigranular. The central and southern parts of the pluton are infested with quartz dioritic enclaves and mafic rich clots. The enclaves in the central part, occurring as clusters, are smaller in size compared to the larger individual enclaves in the southern part, which have preponderance of hornblende over biotite. Well-developed mineral zoning in enclaves is demonstrated by concentration of larger biotite flakes and hornblende laths along the border and relatively smaller biotite, hornblende and plagioclase grains in the core.

The Neoproterozoic age of the batholith is established by Rb-Sr geochronological data which give the crystallization age of $638 \pm 29$ Ma and a $\text{Sr}_0$ value of 0.7093 (Fig. 3). The high initial Sr ratio is suggestive of a significant crustal component in the magma genesis.

**MINERALOGY, NOMENCLATURE AND TEXTURAL ATTRIBUTES**

The Conceição das Creoulas granitoids are porphyritic in nature with coarsely crystalline, equigranular, hypidiomorphic groundmass comprising quartz, K-feldspar, plagioclase (oligoclaseandesine) and biotite. Epidote (up to 5% modal abundance) is the main accessory phase along with titanite, hornblende, apatite and zircon. Myrmekitic intergrowth along grain boundaries of feldspar is a common feature of these granitoids. Plagioclase, the most abundant mineral, has characteristic Albite-Carlsbad twinning. The megacrysts (up to 6 cm long) usually display oscillatory zoning. K-feldspar in the groundmass is mainly microcline-microperthite. Inclusions of quartz, biotite, epidote, hornblende and zircon in K-feldspar are suggestive of its late, near solidus crystallization. Anhedral quartz grains have characteristic wavy extinction and intergrowth with K-feldspar and plagioclase. Absence of Fe-Ti oxide minerals in these granitoids is consistent with other epidote-bearing granitoids (Sial, 1993; Schmidt & Thompson, 1996).

In the QAP diagram (Streckeisen, 1976), the biotite granodiorites plot mainly in the granodiorite field barring six samples that straddle across into the monzonite field. The migmatics from the country rocks plot distinctly away, within the monzogranite field. The enclaves, in correspondence with their mafic character, are quartz diorites and quartz-monzodiorite (Fig. 4).

![whole-rock Rb-Sr isochron](image)

Fig. 3 — Whole-rock Rb-Sr isochron for the Conceição das Creoulas batholith.
Epidote, the most significant accessory phase (ranging from 1.5 to 5% modal abundance) occurs in a number of petrogenetically significant textural relationships:

Type-a epidote occurs as euhedral core, also demonstrates compositional zoning and twinning (Fig. 5a). Type-b epidote is allanite-free, occurring as euhedral to subhedral crystals within biotite (Fig. 5b). Epidote of type c occurs as partly embayed subhedral grains within plagioclase laths (Fig. 5c). These are smaller than those associated with biotite. Type-d epidote is a late crystallizing phase, occurring in the interstices of plagioclase, biotite and hornblende. Type-e epidote is the least abundant type, occurring as subhedral crystals, partly enclosed by biotite. These have a well-preserved euhedral contact against biotite and partly resorbed margins in contact with the felsic minerals (Fig. 5d). In a few cases, biotite and hornblende inclusions are present within this type of epidote (Fig. 5e).

The epidote a, b and c types correspond with types II, III and I, respectively, described by Sial (1990). Distinctive textural attributes of epidotes (euhedral to subhedral crystal geometry, twinning and compositional zoning, presence of allanite core and angular relationship with host minerals) are diagnostic of their magmatic origin.
about 1%). The Ps content varies systematically from the highest values encountered in “type a” epidote (allanite bearing) (Ps24.25), followed by “type b” (Ps21.23) and “type c” (Ps20.21), in the decreasing order (Fig. 6). Limited variation in the Ps content of the suite, a function of fO2, reflects a narrow crystallization pressure range of the system. The pistacite content range of epidote from the Conceição das Creoulas batholith is consistent with crystallization along NNO buffer, and is quite similar to that found in other plutons of the region (Fig. 7) (Sial, 1993).

Decreasing in Ps content of epidote with crystallization is evident as the Ps content of epidote
### TABLE I

Representative electron microprobe analyses of magmatic epidote from the Conceição das Creoulas batholith (r = rim; c = core).

<table>
<thead>
<tr>
<th>Sample</th>
<th>RCC-04</th>
<th>RCC-09</th>
<th>RCC-16</th>
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<tr>
<td>Grain</td>
<td>25</td>
<td>25</td>
<td>35</td>
</tr>
<tr>
<td>SiO₂</td>
<td>38.92</td>
<td>38.82</td>
<td>39.22</td>
</tr>
<tr>
<td>MgO</td>
<td>0.02</td>
<td>0.05</td>
<td>0.09</td>
</tr>
<tr>
<td>CaO</td>
<td>23.42</td>
<td>23.83</td>
<td>23.50</td>
</tr>
<tr>
<td>TiO₂</td>
<td>0.08</td>
<td>0.18</td>
<td>0.03</td>
</tr>
<tr>
<td>MnO</td>
<td>0.13</td>
<td>0.18</td>
<td>0.10</td>
</tr>
<tr>
<td>Total</td>
<td>98.68</td>
<td>98.31</td>
<td>98.98</td>
</tr>
</tbody>
</table>

Number of cations on the basis of 25 oxygen:

| Si     | 3.048  | 3.040  | 3.050  | 3.019  | 2.920  | 2.924  | 3.005  | 3.026  | 3.023  | 3.038  | 3.024  | 3.003  |
| Al     | 2.282  | 2.341  | 2.337  | 2.353  | 2.318  | 2.302  | 2.328  | 2.302  | 2.315  | 2.272  | 2.262  | 2.260  |
| Fe³⁺   | 0.661  | 0.580  | 0.607  | 0.582  | 0.748  | 0.782  | 0.617  | 0.617  | 0.611  | 0.636  | 0.660  | 0.698  |
| Mg     | 0.002  | 0.006  | 0.010  | 0.007  | 0.001  | 0.002  | 0.011  | 0.000  | 0.016  | 0.000  | 0.009  | 0.007  |
| Ca     | 1.965  | 1.999  | 1.958  | 2.052  | 2.026  | 2.009  | 2.018  | 2.028  | 2.035  | 2.036  | 2.011  | 2.008  |
| Ti     | 0.009  | 0.020  | 0.020  | 0.016  | 0.002  | 0.018  | 0.009  | 0.011  | 0.008  | 0.011  | 0.012  | 0.009  |
| Mn     | 0.011  | 0.012  | 0.010  | 0.01  | 0.020  | 0.015  | 0.008  | 0.002  | 0.000  | 0.002  | 0.009  | 0.006  |
| Ps     | 0.22   | 0.20   | 0.21   | 0.20   | 0.24   | 0.25   | 0.21   | 0.21   | 0.21   | 0.22   | 0.23   | 0.24   |

Within early crystallizing biotite to late crystallizing plagioclase decreases from 24-25% to 20-21%. However, a limited variation in Ps content does not effect any significant change in fO₂, which remains within the NNO buffer.

Experimental work on epidote bearing granodioritic melts provides a pressure range of 6-8 kbar for epidote crystallization, corresponding with the depth range of lower crustal levels (Zen & Hammarstrom, 1986). Survival of epidote in higher level intrusive rocks is a consequence of rapid ascent of the magma, at a rate exceeding that of epidote dissolution, at lower pressure (Schmidt & Thompson, 1996). The preservation of epidote at low pressure is also a function of temperature, fO₂ and water content (Schmidt & Thompson, op. cit.). The actual pressure of epidote crystallization in granitic melt would be lowered with fO₂ buffered at higher values (HM). The dissolution kinetics of mEp in granitic magmas at <6 kbar can not be used to precisely estimate the upward migration rate of the melt due to its dependence upon additional factors (Brandon et al., 1996). The epidote dissolution is a function of time, crystal size and temperature. However, the presence of epidote in shallower level granitic emplacements is a conclusive evidence of high-pressure origin of the melt and its rapid upward migration.
Fig. 6 — Textural types of epidote versus atomic Fe$^{3+}/$(Fe$^{3+}$+Al) ratios for the Conceição das Creoulas batholith.

Fig. 7 — Mole % pistacite in magmatic epidote of the Cachoeirinha-Salgueiro terrane (Sial, 1993). Conceição das Creoulas batholith and pistacite compositions of non magmatic epidote. The ranges of epidote from alteration of plagioclase and biotite are from Tulloch (1979) and for igneous epidote, from Johnston & Wyllie (1988).
HORNBLENDE CHEMISTRY

The amphiboles of Conceição das Creoulas batholith are calcic amphiboles (Fig. 8a; Leake et al., 1997). The hornblende in the porphyritic granites is ferropargasite, whereas the composition of amphiboles from the enclaves cluster in corner between edenite-ferroedenite-magnesiohastingsite in Mg/(Mg+Fe) vs Si diagram (Fig. 8b). The Mg/(Mg+Fe) ratio (0.40-0.58) is in accordance with the ranges for calc-alkalic granitoids (Mason, 1985), while the Fe/(Fe+Mg) ratios suggest crystallization of this phase under moderate $f_0_2$.

The variation of Al content of amphiboles in calc-alkalic granitoids varies with crystallization pressure. The empirical barometric equation, proposed by Hammarstrom & Zen (1983, 1986) has been subsequently subjected to refinement and calibration to increase the precision level to 1 kbar (Hollister et al., 1987; Johnston & Rutherford, 1989; Rutter et al., 1989). The calibrations proposed by Schmidt (1992) approach the empirical, field based calibrations of Hammarstrom & Zen (1986). Due to their applicability up to 13 kbar pressure level and maximum Al up to 3.37 atoms per formula unit, the calibrations proposed by Schmidt (1992) have been used in the present work, for their suitability.

The results of geobarometric calculations of this study are shown in Table II. Pressure estimates, as per Hollister et al. (1987) and Hammarstrom & Zen (1986) have also been given, for comparison. The data suggests a pressure range of 6.4-7.0 kbar for enclaves and 8.0 kbar for porphyritic granodiorites. This also rules out any possible genetic link between mafic enclaves and granodiorites.

Contrasting geochemical signatures of enclaves and granodiorites further preclude any consanguinity between the two (Brasilino, 1997). The enclaves appear to be incorporated by the ascending magma, very close to the place of origin. The sinking of the mafic fragments (enclaves) appears to have been prevented by high viscosity and buoyancy of the melt, resulting in concentration of the enclaves along the roof of the pluton. Concentration of enclaves along the southern part of the pluton may be a result of southward tilt of the pluton (synchronous with its emplacement), resulting in plastic movement of the enclaves. Structural work, however, must be made to confirm this hypothesis.

HORNBLENDE – PLAGIOCLASE THERMOMETRY

The amphibole-plagioclase thermometry, proposed by Blundy & Holland (1990) is valid for a temperature range of 500-1000°C for plagioclase with <7.8 Si atoms per formula unit. The level of uncertainty in these calculations was subsequently reduced from ±75°C to ±35°C (Holland & Blundy, 1994). The newer calibration was used here since it offers better precision. The geothermometric estimates, as given in Table II, indicate a crystallization temperature of 670-686°C for enclaves than near solidus at 6 and 8 kbar, respectively. The granodiorites exhibit similar temperatures ranges (680-690°C) near solidus, at both 6 and 8 kbar pressures.

Zr THERMOMETRY

Whole-rock Zr abundance can be used to estimate the crystallization temperature of zircon in Zr saturated granitic melts (Watson, 1987). This method can only be applied with an assumption that the zircon is not inherited from the source and does not represent a cumulate phase. Based upon the fact that zircon is usually the first mineral to crystallize, the Zr thermometric estimates are appropriate for deducing the minimum liquidus temperature. In the present case, these liquidus temperatures have been estimated as 790-830°C for enclaves and 800-850°C for granodiorites (Table III). The only possible inconvenience is the presence of inherited zircons that can partially account for the Zr contents detected in whole-rocks analyses, leading to false temperature estimates.

These calculations are important, since they provide the only evidence of minimum liquidus temperatures that may be comparable to conditions of melting formation.

The geobarometric and geothermometric estimates based upon different methods are in general
Fig. 8 — (a) Composition and classification of the amphiboles. After Leake et al. (1997), amphiboles from the porphyritic granodiorite (CCB); (b) classification of the amphiboles (Leake et al., 1997). Symbols: (●) porphyritic granodiorites/monzogranites, (▲) microgranular mafic enclaves.
TABLE II
Hornblende thermobarometry of samples from Conceição das Creoulas batholith.

<table>
<thead>
<tr>
<th>Rock type</th>
<th>AIT</th>
<th>P1(kbar)</th>
<th>P2(kbar)</th>
<th>P3(kbar)</th>
<th>T1(°C)</th>
<th>T2(°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>enclave</td>
<td>2.112</td>
<td>6.70</td>
<td>6.70</td>
<td>7.04</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.978</td>
<td>6.03</td>
<td>6.40</td>
<td>6.40</td>
<td>677</td>
<td>672</td>
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<tr>
<td></td>
<td>2.034</td>
<td>6.31</td>
<td>6.71</td>
<td>6.68</td>
<td>686</td>
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<td>porphyritic</td>
<td>2.306</td>
<td>7.66</td>
<td>8.23</td>
<td>7.96</td>
<td>674</td>
<td>677</td>
</tr>
<tr>
<td>granodiorite</td>
<td>2.338</td>
<td>7.84</td>
<td>8.43</td>
<td>8.12</td>
<td>693</td>
<td>691</td>
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<td></td>
<td>2.298</td>
<td>7.64</td>
<td>8.20</td>
<td>7.91</td>
<td>680</td>
<td>683</td>
</tr>
</tbody>
</table>

Note. (P₁) hornblende solidification estimates based upon Hollister et al. (1987) calibration; (P₂) pressure based upon Hammarstrom & Zen (1986); (P₃) pressure based upon Schmidt (1992); (T₁) temperature hornblende-plagioclase pair solidification estimates based upon Holland & Blundy (1994) for P=6kbar and (T₂) temperature hornblende-plagioclase pair solidification estimated based upon Holland & Blundy (1994) for P=8kbar.

correspondence with each other and point towards a slightly higher P-T conditions for granodiorites as compared to the enclaves.

SUMMARY AND CONCLUSIONS

Intrusive relationship of Conceição das Creoulas batholith with basement migmatites is manifested in its emplacement athwart to the regional tectonic grain. The temporal distinction between the two is also brought out by whole rock Rb-Sr age of 638 ± 29 Ma for Conceição das Creoulas batholith. The dioritic enclaves, do not represent xenoliths of the source rock but appear to have been incorporated by the melt during early stages of magmatic ascent. Contrasting geochemical behavior of enclaves and host granodiorites is reflected in absence of any continuity of fractionation trends, between the two (Brasilino, 1997). The estimated crystallization pressure and temperature for enclaves are also slightly lower as compared to the host granitoids.

The occurrence of mEp in various textural relationships indicates the extended crystallization range of epidote. The geobarometric and geothermometric estimates (hornblende-plagioclase) indicate crystallization pressure 8 kbar and a temperature >675°C. The pressure-temperature calculations, using different parameters are complimentary to each other and underline the origin at lower crustal depths with significant crustal component. The whole-rock Zr thermometry gives a minimum melt temperature of 850 to 800°C. The difference between temperatures indicates long interval of crystallization for the CCB. Abundance of mEp is also consistent with melt generation at the lower crustal depth and ultimate emplacement at less deep level. Assuming that the top of the pluton represents the roof of original magma chamber (with enclaves concentrated at the top), the elliptical and rounded outcrop pattern of the pluton apparently represents a diapirc head.

The occurrence of mEp as the most abundant accessory phase, on the contrary, is a conclusive evidence of rapid upward magma transport, which is not usually associated with diapiric upwelling. Therefore, it is assumed here that magma moved upward by diking, inflating outwards near or at the final site of emplacement.

The tectonic model of emplacement thus can be envisaged as that of a lower crustal depth of magma generation and rapid ascent through diking. The diapirc shape of the pluton appears to be related to lateral inflation at shallow emplacement levels. A southward tilt of the pluton, almost synchronous with emplacement appears to have induced a plastic movement of enclaves that now appear to be segregated and concentrated along the southern part of the pluton.

TABLE III
Temperatures for Conceição das Creoulas batholith, calculated from
Zr saturation equation of Watson (1987).

<table>
<thead>
<tr>
<th>Sample</th>
<th>Zr (ppm)</th>
<th>°C</th>
<th>Rock type</th>
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<tr>
<td>RCC-05E</td>
<td>279</td>
<td>826</td>
<td>microgranular mafic enclave</td>
</tr>
<tr>
<td>RCC-19E</td>
<td>162</td>
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<td>RCC-20E</td>
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<td>840</td>
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REFERENCES


CORNELIUS, H. P. (1915), Geologische Beobachtungen im Gebiet des Forno-Gletschers (Engadin). Zentralblatt für Mineralogie und Paläontologie 1913, 8: 246-252.


