RELATIONS BETWEEN PEGMATITE EMPLACEMENTS AND TECTONO-METAMORPHIC EVENTS IN THE SERIDÓ GROUP, NORTHEASTERN BRAZIL

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RESUMO RELAÇÕES ENTRE POSICIONAMENTOS DE PEGMATITOS E EVENTOS TECTONO-METAMÓRFICOS NO GRUPO SERIDÓ, NORDESTE DO BRASIL. As relações de idade dos pegmatitos com as fases de dobramentos regionais (F_2 e F_3) e suas feições estruturais sugerem a existência de duas suítes distintas destes corpos no Grupo Seridó: uma suíte mais antiga (pré- F_3) de pegmatitos intensamente deformados, apresentando, localmente, tramas tectônicas relacionadas a F_2 e/ou F_3 e outra mais nova (tarde após F_3) compreendendo corpos pouco deformados ou não-deformados e sem qualquer trama tectônica. A maior concentração de pegmatitos, incluindo os membros de ambas as suítes, ocorre em metassedimentos de médio a alto grau, na parte leste da faixa Seridó. As estruturas e tramas tectônicas encontradas nos pegmatitos da suíte mais antiga mostram que seu posicionamento teve início durante o evento tectono-metamórfico regional F_2 e terminou antes de F_3 . As relações estruturais dos pegmatitos da suíte mais nova, e a ausência, nestes corpos, de tramas planares e lineares, sugerem que os mesmos foram posicionados posteriormente à fase de cristalização/recristalização sintectônica relacionada ao evento tectono-metamórfico regional F_3 . As idades de dois pegmatitos da suíte mais nova estão situadas entre 510 a 450 Ma, o que indica uma idade tardi-brasileiana para sua colocação. Esta suíte pegmatítica parece ser geneticamente relacionada a granitos brasileiros tardi-tectônicos (com idades de 570 a 510 Ma). Não é possível estabelecer no presente a idade da suíte mais antiga, assim como sua relação com os granitos, por falta de dados geocronológicos e geoquímicos. Contudo, não há dúvida que seu posicionamento ocorreu cedo na história tectono-metamórfica do Grupo Seridó.

Palavras-chaves: Suítes de pegmatitos, episódios de posicionamento de pegmatitos, fases de dobramento, eventos metamórficos, magmatismo granitóide, Grupo Seridó, Nordeste brasileiro.

ABSTRACT The age relationships of pegmatites to the regionally important folding phases (F_2 and F_3) and their deformation features suggest the existence of two distinct suites of pegmatites in the Seridó Group: an older (pre- F_3) suite of highly deformed pegmatites showing, locally, tectonic fabrics related to F_2 and/or F_3 ; and a younger (late-post F_3) suite of weakly deformed or undeformed pegmatites without any tectonic fabric. The major concentration of pegmatites, including members of both the suites, occurs within medium- to high-grade metasediments in the eastern part of the Seridó belt. The tectonic structures and fabrics found in pegmatites of the older suite show that their emplacement began during the regional F_2 tectono-metamorphic event and outlasted it. The structural relationships of pegmatites of the younger suite, together with their lack of planar and linear fabrics, suggest that their emplacement post-dates the phase of syntectonic crystallization related to the regional F_3 tectono-metamorphic event. The ages obtained for two pegmatites of the younger suite are situated between 510 and 450 Ma, which suggests a late Brazilian age for its emplacement. This pegmatite suite appears to be genetically related to the late-tectonic (570-510 Ma old) Brazilian granites. The age of the older pegmatite suite, as also its relationship with the granites, cannot be established at present for lack of geochronological and geochemical data. However, there is no doubt that its emplacement occurred early in the tectono-metamorphic history of the Seridó Group.

Keywords: Pegmatite suites, pegmatite emplacement episodes, folding phases, metamorphic events, granitoid magmatism, Seridó Group, Northeastern Brazil.

INTRODUCTION It is known from the previous studies that the Proterozoic supracrustal rocks of the Seridó group, occupying a large area in the state of Paraíba and Rio Grande do Norte, have a polyphase structural and metamorphic history. Their tectono-metamorphic evolution has involved at least five phases of deformation (F_1 - F_5), accompanied by low to intermediate pressure type metamorphism varying from amphibolite to green-schist facies (Mello & Mello 1974, Salim *et al.* 1979, Martins Sá & Legrand 1983, Jardim de Sá 1984). The metamorphic grade in general increases from west to east across the supracrustal belt (Mello & Mello 1974). In the large areas of the northeastern part of the belt, Salim *et al.* (1979) and Martins Sá & Legrand (1983) have defined a succession of metamorphic phases roughly synchronous with deformation phases. Their results show that the climax of regional metamorphism occurred during F_2 , attaining the amphibolite facies at the anatectic isograd, and was marked by the formation of such minerals as cordierite, sillimanite and diopside, and of migmatites. Lima (1987) has carried out a regional study of the metamorphic history of the supracrustal

rocks and has recognized two major metamorphic events, broadly synchronous with respectively F_2 and F_3 deformations and ranging in grade from lower to upper amphibolite facies. His results show that P-T conditions during the second event increased from west to east, reaching a maximum in the central part of the belt, and that the metamorphic grade during this event attained the sillimanite isograd. In his view the mineral assemblages which crystallized during the first metamorphic event have undergone a partial to total re-equilibration during the second event. The Seridó supracrustal sequence is intruded by a huge volume of granitic rocks. These have been ascribed to more than three periods of emplacement by Jardim de Sá *et al.* (1981). Rb-Sr and U-Pb ages of different suites of granites have been interpreted by Macedo *et al.* (1984), Jardim de Sá *et al.* (1988) and Bertrand & Jardim de Sá (1990) to show that the Seridó supracrustal rocks have a polycyclic history, having been deformed and metamorphosed during the Transamazonian orogeny before being affected by the Brazilian deformation and metamorphism. This view is contested by other workers who

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favour the idea of a monocyclic (Brasiliano) evolution for the Seridó supracrustal belt (Caby & Arthaud 1986, Caby *et al.* 1987, Caby 1989).

Besides granites, a large number of granitic pegmatites, both homogeneous and heterogeneous (with internal zoning), is associated with the Seridó supracrustal rocks. They are composed of essentially muscovite, quartz and microcline, and show a variable degree of albitization. A majority of these bodies is mineralized and has yielded thousands of tons of valuable minerals such as beryl, columbite-tantalite, cassiterite, spodumene and others since the beginning of the Second World War. Owing to the occurrence of tin-bearing pegmatites in this region (also known as Borborema Pegmatite Province), the same has been included by Schuiling (1967) in his "tin belt" which extends from Rio Grande do Sul up to Ceará and Rio Grande do Norte in eastern Brazil, and which continues into Nigeria and Hoggar on the African side. The age(s) of emplacement of pegmatites and their relationships to the tectonothermal events in the Seridó Group have not been established yet. Only six pegmatites have been dated so far (Marble 1949, Dirac & Ebert 1967, Almeida *et al.* 1968, Ebert 1969). The ages for five of them are situated between 550 and 450 Ma. The age obtained for the sixth pegmatite is 780 Ma. These age data have been interpreted by previous workers as suggesting a late to post-tectonic (Brasiliano) age for the pegmatites in general, Almeida *et al.* 1968, Brito Neves *et al.* 1974, Pessoa 1974, Galindo 1981, Brito Neves 1983, Jardim de Sá 1984). A recent study (Agrawal 1986) of the relationships of pegmatites to the structural sequence has, however, revealed more than one period of pegmatite emplacement in the Seridó supracrustal belt. The aim of the present paper is to discuss the relations of pegmatite emplacement episodes and the tectono-metamorphic events in this belt.

AGE RELATIONSHIPS OF PEGMATITES TO THE REGIONALLY IMPORTANT FOLDING PHASES A

study of the relationships of pegmatites to mesoscopic structural elements of the enclosing rocks (Seridó group) was carried out in the eastern part of the Seridó belt (between 36° and 37°W long, and 6° and 7°S lat.), particularly in the municipalities of Juazeirinho - PB, Pedra Lavrada - PB, Nova Palmeira - PB, Picuí - PB, Frei Martinho - PB, Acari - RN, Carnaúba dos Dantas - RN, Parelhas - RN and Junco do Seridó - PB which together cover the area of the major concentration of pegmatites (Fig. 1). In the area studied he pegmatites mostly occur within garnet-biotite schists (with or without cordierite and andalusite/sillimanite) of the Seridó formation or within the micaceous quartzites of the Equador formation. The mesoscopic structures developed in these rocks correspond to F₁, F₂, F₃ and F₅ structures of the regional structural sequence proposed by Jardim de Sá (1984). On the basis of their relationships to the structural elements representing regionally important folding phases (F₂ and F₃), it is possible to divide the pegmatites into following four groups:

1. Pegmatites which are concordant with the principal foliation (S₂) and are deformed by F₃ folds (subgroup 1 of Agrawal 1986).

2. Pegmatites which cut the principal foliation (S₂) and the intrafolial F₂ folds but which are folded by F₃ folds (subgroup 2 of Agrawal 1986).

3. Pegmatites which cut the principal foliation (S₂) and the F₂ folds which appear to follow the axial plane of F₃ folds.

4. Pegmatites which cut F₃ folds.

From their age relationships to F₂ and F₃ folds, it is clear that the pegmatites of the Seridó Group occupy more than one position on the structural time scale (Fig. 2). They also differ markedly in the intensity of their deformation, pegmatites of group 1 and 2 being far more deformed than those of group 3 and 4. Group 1 pegmatites, which are concordant with S₂, commonly show development of pinch-and-swell and

Figura 1 - Esboço geológico da porção oriental da faixa Seridó, Rio Grande do Norte e Paraíba (adaptado e modificado de Leterrier *et al.* 1990) mostrando a localização das áreas ricas em pegmatitos: 1. cobertura mesozóica-cenozóica; 2. granitos brasileiros; 3. ortogneisses transamazônicos; 4. Grupo Seridó (Proterozóico Inferior), compreendendo as Formações Jucurutu (J), Equador (E) e Seridó (S); 5. Complexo Caicó (Arqueano-Proterozóico Inferior); 6. áreas ricas em pegmatitos

Figure 1 - Geological sketch map of the eastern part of the Seridó belt, Rio Grande do Norte and Paraíba (adapted and modified from Leterrier *et al.* 1990) showing the locations of the pegmatite-rich areas: 1. Mesozoic-Cenozoic cover; 2. Brazilian granites; 3. Transamazonian orthogneisses; 4. Early Proterozoic Seridó Group, comprising the Jucurutu (J), Equador (E) and Seridó (S) formations; 5. Archean to Early Proterozoic Caicó Complex; 6. pegmatite-rich areas

boudinage structures. They locally show development of a planar fabric parallel to S₂ and are folded by F₃ and later folds. Group 2 pegmatites, which cut F₂ folds but which are folded by F₃, locally show development of a coarse foliation (S₃) parallel to the F₃ axial plane. This foliation is defined by a preferred dimensional orientation of quartz, feldspar and mica. In some cases a mineral lineation related to F₃ is also developed, defined variably by aggregates of such minerals as quartz, feldspars, garnet and sillimanite. In contrast, the pegmatites of group 3 and 4 generally occur as weakly deformed (or undeformed) tabular bodies which do not show any tectonic fabric (F₂ or F₃). The only evidence of deformation found in them is fracturing.

On deformation criteria it is possible to distinguish two distinct suites of pegmatites in the Seridó Group: 1. an older suite of highly deformed pegmatites with some kind of tectonic fabric (groups 1 and 2); and 2. a younger suite of weakly deformed or undeformed pegmatites without any tectonic fabric (groups 3 and 4). The pegmatites of the older suite predate the regional F₃. The structural features present in them suggest that their emplacement began sometime during the F₂ fold phase and ended before the incidence of F₃ folding. The emplacement of the younger suite seems to have

EASTERN PART OF THE SERIDÓ SUPRACRUSTAL BELT			
REGIONAL FOLDING PHASES (Jardim de Sá, 1984)	PERIODS OF CRYSTALLIZATION OF METAMORPHIC MINERALS (Lima, 1987)	PERIODS OF PEGMATITE EMPLACEMENT	AGE Ma
	Growth of Cordierite	younger suite	510 to 450
F ₃	Growth of biotite, garnet, staurolite, cordierite, andalusite, sillimanite, plagioclase (An 20-50)		
	Growth of garnet, cordierite		
F ₂	Growth of biotite, garnet, staurolite	older suite	?
	Growth of garnet		
F ₁			

Figura 2 - Período de posicionamento de pegmatitos em relação às fases de dobramentos regionais e episódios metamórficos no Grupo Seridó

Figure 2 - Periods of pegmatite emplacement in relation to regional folding phases and metamorphic episodes in the Seridó Group

begun in the last stages of the F₃ fold phase and to have outlasted it.

AGES OF PEGMATITE EMPLACEMENT EPISODES

Very few (about six) pegmatites have been dated so far from the Seridó belt. Among them, the structural relationships of only two pegmatites are clearly defined. These are: 1. Alto Seridozinho in Juazeirinho - PB and 2. Alto Boqueirão in Parelhas - RN. Their ages, obtained from six K-Ar muscovite analyses, two U-Pb uraninite analyses and one Rb-Sr muscovite analysis, are situated between 510 and 450 Ma (Marble 1949, Dirac & Ebert 1967, Almeida *et al.* 1968, Ebert 1969). Both these pegmatites are weakly deformed with development of fractures but without any tectonic fabric. Alto Seridozinho cuts F₂ folds and appears to follow the axial plane of F₃ (group 3). Alto Boqueirão appears to post-date the F₃ folds (group 4). Their ages thus suggest a late Brasiliano age for the episode of emplacement of the younger suite of pegmatites in the Seridó Group. As regards the older (pre-F₃) suite of pegmatites (group 1 and 2), no geochronological data are available on them at the moment. However, a rough age for the emplacement of concordant pegmatites (group 1) can be inferred from the age of F₂ deformation event. Macedo *et al.* (1984) and Jardim de Sá *et al.* (1988) have interpreted the Rb-Sr whole rock ages (2.0-1.9 Ga) of granite augen gneisses, which they regard as syntectonic intrusions, as indicative of a Transamazonian age for the regional F₂. As concordant pegmatites, lying parallel to the S₂ foliation, show evidence of extension in this plane and development, locally, of F₂ fabric, it follows that their emplacement should date back to Transamazonian time, if that age is accepted for the regional F₂. In the absence of geochronological date on the older suite of pegmatites, however, it is not possible at present to establish a precise age for their emplacement or the time interval separating them from the younger suite.

RELATIONSHIPS OF PEGMATITES WITH METAMORPHISM AND GRANITOID MAGMATISM

The major concentration of both the older (groups 1 and 2) and

the younger suite (groups 3 and 4) of pegmatites occurs within medium- to high-grade metasediments in the eastern part of the Seridó supracrustal belt. Two main events of regional metamorphism, broadly synchronous with, respectively, F₂ and F₃ deformations, have been identified in this belt by Lima (1987). His results show that the metamorphic grade during these events varied from lower to upper amphibolite facies in the main pegmatite field. The parallelism of group 1 pegmatites with S₂ (i.e. axial plane of F₂), together with their locally developed planar fabric lying in the same plane, show that their emplacement occurred during the F₂ tectono-metamorphic event. On the other hand, the cross-cutting relationship of group 2 pegmatites with F₂ structures and the evidence of their deformation and recrystallization during the F₃ tectono-metamorphic event suggest that their emplacement began after the F₂ tectono-metamorphic event and ended before F₃. Thus, considering the older suite of pegmatites as a whole, its emplacement seems to be syn- to post-tectonic in relation to the regional F₂ tectono-metamorphic event (Fig. 2). Salim *et al.* (1979) and Martins Sá & Legrand (1983) have shown that the regional metamorphism during F₂ attained the anatexis isograd in the northeastern part of the Seridó belt and was accompanied by the formation of migmatites. It is therefore possible that some of the older pegmatites, especially the concordant (group 1) pegmatites associated with the high-grade schists, are the product of regional metamorphism. The structural relationships of pegmatites of the younger suite, together with their lack of planar and linear fabrics, suggest that their emplacement post-dates the phase of syntectonic crystallization/recrystallization related to the regional F₃ tectono-metamorphic event (Fig. 2).

The ages obtained for the pegmatites of the younger suite, bearing Nb-Ta-Sn-Li mineralization, are situated between 510 and 450 Ma (Marble 1949, Dirac & Ebert 1967, Almeida *et al.* 1968, Ebert 1969), whereas the late-tectonic Brasiliano granitic intrusions have been dated between 570 and 510 Ma (Jardim de Sá *et al.* 1988). This seems to suggest that the emplacement of the younger suite of pegmatites closely followed that of the late-tectonic granites. It is possible that the two are genetically related. In the Pan-African belt of the Hoggar-Nigeria shields, which is considered to be the continuation of the Brasiliano orogenic belt of northeast Brazil (Torquato & Cordani 1981, Lesquer *et al.* 1984, Porada 1989, Caby 1989, Bertrand & Jardim de Sá 1990) and where granitic pegmatites carrying the Sn-Nb-Ta mineralization also occur, the trace-element chemistry of muscovites from the latter and the associated granites have been studied by Kilster (1990). He has presented data to show that the late-tectonic (550 Ma old) Pan-African granites (the leucogranites, are the parental sources of 530 Ma old pegmatites bearing the Sn-Nb-Ta mineralization. It seems very likely that the younger suite of the Seridó pegmatites is similarly related to the late-tectonic Brasiliano granites. However, their exact relationship needs to be identified through a detailed geochemical investigation. As regards the older suite of Seridó pegmatites, neither geochronological nor geochemical data are available on them. It is therefore not possible at this stage to assess their relationships with the granites.

CONCLUSIONS On structural criteria, two suites of pegmatites can be distinguished in the Seridó Group: an older (pre-F₃) suite of highly deformed pegmatites with locally developed planar and linear fabrics related to F₂ and/or F₃; and a younger (late-post F₃) suite of weakly deformed or undeformed pegmatites without any tectonic fabric.

From the structural relationships of pegmatites and the tectonic fabrics found in them it appears that the emplacement of the older suite is syn- to post-tectonic in relation to the regional F₂ tectono-metamorphic event, whereas that of the younger suite post-dates the phase of syntectonic mineral growth related to the regional F₃ tectono-metamorphic event.

The younger (roughly 510-450 Ma old) suite of pegmatites is of a late Brasiliano age and is probably genetically related to the late-tectonic (570-510 Ma old) Brasiliano granites. The age of the older pegmatite suite, as also its relationship with the granites, cannot be established at present for lack of geochronological and geochemical data, but there is no doubt that its emplacement occurred early in the tectono-metamorphic history of the Seridó supracrustal rocks.

A radiometric dating of different groups (1-4) of the ages of their emplacement, and can also be useful in establishing

the ages of the tectono-metamorphic events in the Seridó Group. In the Moines of Scotland, for example, a Precambrian orogeny (the Morarian) has been established on the basis of the radiometric ages of pegmatites with known structural relationships (Van Breemen *et al.* 1974, Piasecki & Van Breemen 1979, Piasecki *et al.* 1981).

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