Brazilian Gem Provinces

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Summary
Emerald, alexandrite, aquamarine, tourmaline, topaz, crysoberyl, amethyst, agate, opal, and morganite are the main coloured gemstones produced in Brazil. The Brazilian gem provinces are located in three different geotectonic settings characterised as Neoproterozoic cratons, Neoproterozoic-Cambrian mobile belts, and Paleozoic-Mesozoic basins. The main gemstones found in the cratonic provinces are emerald, imperial topaz, and quartz varieties. These mineralizations are usually linked to hydrothermal systems. In the Neoproterozoic-Cambrian mobile belts, innumerable pegmatites, grouped in various provinces, bear mineralizations of aquamarine, tourmaline, morganite, blue to colourless topaz, hiddenite, kunzite, and quartz varieties, among others. Emerald and alexandrite occur in hydrothermal systems in those belts. Silica minerals, chiefly amethyst, opal and agate, are the main gemstones found in the provinces located in the Paleozoic-Mesozoic basins.

Introduction
"Brazil contains the world's largest and most diversified gemstone province", wrote Patrick Delaney (1996) in "Gemstones of Brazil", his last legacy to Brazilian gemmology. Besides Delaney's work, an essential source of information on Brazilian gemstones is the book named "*Gemas e Rochas Industriais*" published by the Brazilian bureau of mines, the *Departamento Nacional da Produção Mineral* (Schobbenhaus *et al.* 1991). In Brazil, coloured gemstones have been extracted since the 18th century. The gem production strikingly increased during and after the World War II, initially due to the intensive exploration of many pegmatite mines, and afterward due to discoveries of emerald and alexandrite deposits. Taking into account Delaney's statement in a modified version, we group the Brazilian gemstone deposits in gem provinces. This paper presents a concise synthesis on these outstanding gem provinces and their groupings of gemstone deposits, together with general approach on the mineralizations controls and genesis. Diamond is beyond the scope of this paper.

Gem Provinces
The Brazilian gem provinces are located in three different geotectonic settings characterised as Neoproterozoic cratons, Neoproterozoic-Cambrian mobile belts, and Paleozoic-Mesozoic basins (Fig. 1). The cratons (rigid continental blocks) and mobile belts (orogens) resulted from the Brasiliano-Pan African Cycle, a set of diachronic orogenies that lasted from at about 850 Ma to 550 Ma and resulted from the assembly of the Western Gondwana paleocontinent (Brito-Neves *et al.* 1999). In the Neoproterozoic cratons occur the homonymous São Francisco (SF) and Amazonia (A) gem provinces. The Neoproterozoic-Cambrian orogenic belts are the sites of the Eastern (E), Northeastern (NE), and Tocantins (T) gem provinces. In the Paleozoic-Mesozoic basins are located the Rio Grande do Sul (RS) and Piauí (P) gem provinces. These provinces may be subdivided into subprovinces and districts.

Gem Provinces in Cratons
The most important population of gem deposits in cratonic setting is the São Francisco province. It includes the Bahia subprovince (Fig. 1; 15, 16, and 19 to 26; Couto 2000), in the north portion of the São Francisco craton, and the Ouro Preto district, in the southern toe of this craton (28). The emerald deposits of the Bahia subprovince are felsic veins, formed by hydrothermal process related to granitic intrusions of Paleoproterozoic age, in ultramafic schists (19, Campo Formoso; 20, Socotó; 21, Anagé). In the Chapada Diamantina region, gemstones of the quartz group (amethyst, rutilated quartz, rock-crystal) occur in veins and geodes hosted by quartzite and felsic to intermediate metavolcanic rocks of Paleoproterozoic to Mesoproterozoic age (22 to 26). Rose quartz is extracted from veins enclosed by granulite facies rocks (16), and amazonite occurs in the Itiúba alkaline intrusion (15). Both these deposits are of Paleoproterozoic age. Since 1750, the sherry wine to honey coloured topaz, called imperial topaz, has been explored in the Ouro Preto district (28). This unique topaz crystallised in vein-like pockets along a fault zone, cutting across a pile of dolomite and phyllite, as an outcome of hydrothermal process probably related to volcanism (Ferreira 1991).
The Amazonia gem province is poorly known. Thirty-seven deposits grouped in four areas scattered over a large region outlined the Pará subprovince (Fig. 1; 45 to 48). Amethyst, rock-crystal, citrine, opal, morion (black quartz), tourmaline, garnet, topaz, malachite, and azurite have been explored in this subprovince (Collyer *et al.* 1994). In the Rondônia district occur topaz (49) associated with granitic intrusions, and amethyst and aquamarine (50) in pegmatites hosted by metavolcanic-sedimentary rocks (Scandolara *et al.* 1998).

Gem Provinces in Mobile Belts
We loan the names of two pegmatite provinces (Paiva 1946) for the designation of the Northeastern and Eastern gem provinces. In historical and economic terms, these are the most important populations of coloured gem deposits in Brazil.
The Northeast province may be subdivided into the lithium-rich Borborema subprovince, at the northern portion of the province, and the beryllium-rich Jaguaribe subprovince (Delaney 1996). The most important groupings of gem deposits of the Northeastern province are the following districts: southern (7, tourmaline, aquamarine, garnet, lazulite), central-southern (8, aquamarine), southwestern (9, emerald, aquamarine; Moraes 1999), Juazeiro (10, pegmatite minerals), Sumé (11, apatite), Cristais-Russas (12, pegmatite minerals), Solonópole (13, pegmatite minerals; Delgado and Pedreira 1995), and São Raimundo Nonato region (14, tourmaline, amethyst, rock-crystal, Oliveira 1998).
Netto *et al.* (1998) concisely described more than 900 gem mines (*garimpos*) along the Eastern gem province. This province includes two distinct types of gem mineralizations: pegmatites *stricto sensu* and hydrothermal deposits (Correia-Neves *et al.* 1986; Pedrosa-Soares *et al.* 2000). The pegmatites mineralised in gem-quality minerals derived from S-type and I-type granites. The intrusive S-type granites are the source of tourmaline-rich and/or lithium-rich pegmatites. These granites formed by partial melting of metasedimentary rocks, and crystallised in intermediate crustal levels. The most fertile pegmatites are thick bodies intruded in quartzite-schist sequences. These pegmatites are the main source of gem-quality tourmalines, morganite, rose quartz, citrine, blue topaz, and innumerable collection pieces, as well as of lithium

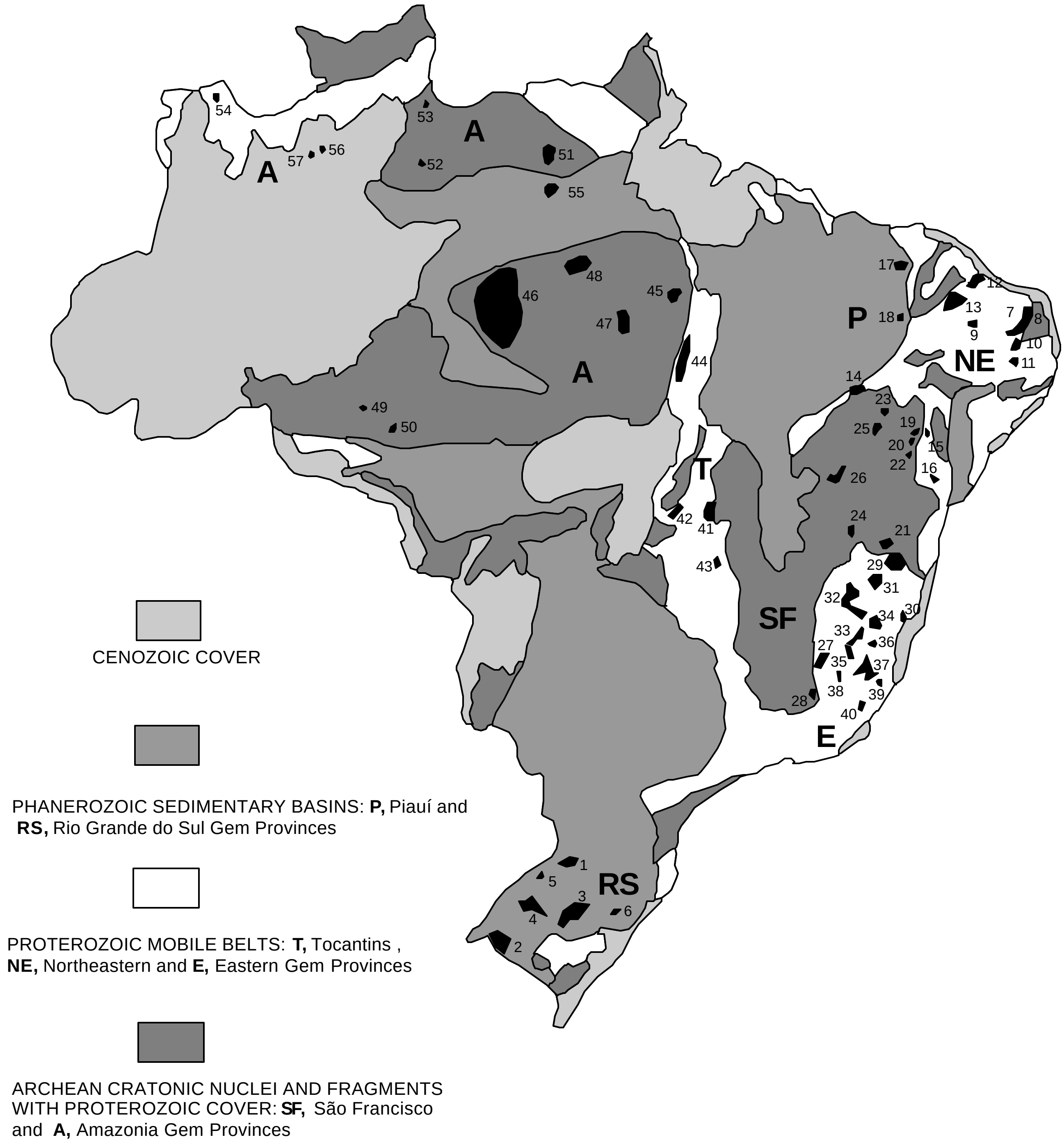

Fig. 1 : Brasilian Gem Provinces

ores (spodumene, petalite, lepidolite, ambligonite-montebrasite). The intrusive S-type granites and the related pegmatites formed during distinct episodes of granitogenesis (Pedrosa-Soares *et al.* 1999) dated at 585-570 Ma (*e.g.*, Conselheiro Pena district; Fig. 1, 37) and 530-520 Ma (*e.g.*, 32, Araçuaí and 33, São José da Safira districts). The tourmaline-poor or free, aquamarine-rich pegmatites are derived from intrusive granites usually with charnockitic facies. These rocks crystallised from iron-rich, high-K calc-alkaline magmas in deep crustal levels, at about 520-500 Ma. Their residual pegmatites are simple-zoned thin bodies, generally emplaced within the parent granite. Crysoberyl is frequently found in alluvial deposits close to the pegmatite occurrences. The main aquamarine deposits of the Eastern province occur in the Padre Paraíso (34) and Medina-Pedra Azul (31) districts. Aquamarine is also the main gemstone produced by the Itambé-Maiquinique (Fig. 1; 29), Itanhém (30), Golconda (35), Ataléia (36), Caratinga (38), Colatina (39), and Mimoso do Sul (40) pegmatitic districts.

Hydrothermal deposits are the source of most emerald and alexandrite extracted in the Eastern gem province from deposits located in the (Fig. 1; 27, Santa Maria de Itabira district; and Malacacheta region located at the southernmost part of the Araçuaí district, 32). Both mineralizations resulted from the interaction of beryllium-rich fluids with the host peraluminous schists and ultramafic rocks. In Malacacheta region, Cambrian (537 ± 8 Ma), S-type, intrusive granites induced hydrothermal alteration by Be-rich fluids in a package of peraluminous schists and metaultramafic rocks, giving rise to the primary alexandrite mineralization (Basílio 1999). The emerald mineralization in the Santa Maria de Itabira district (Machado 1999) also seems to be related to a hydrothermal process that took place at about 509 Ma (Ribeiro-Althoff *et al*. 1997).

The Tocantins province also includes pegmatite-hosted gems namely, aquamarine, crysoprazio, rock-crystal, amethyst (Fig. 1, 41, Minaçu region) and hydrotermal deposits of emerald (42, Santa Terezinha de Goiás), rock-crystal (43, Cristalina) and amethyst (44, Pau D'Arco, Conceição do Araguaia). Santa Terezinha de Goiás is probably the most important Braszilian emerald producer; the gems are related to felsic hydrotermal fluids in mafic-ultramafic schists.

Gem Provinces in the Paleozoic-Mesozoic Sedimentary Basins

1. Southern Brazilian (Rio Grande do Sul) Gem Province (RSGP)

This large province covers the southernmost domain of the Paraná Basin in Brazil, mostly in Rio Grande do Sul State, southern Brazil. The province is assigned to the Mesozoic Paraná flood basalts flows and produces some of the largest amethyst-bearing geodes all over the world; some of them reaching up to 3 tons. The geodes are found in the intermediate and upper zones of the flows. The deposits are concentrated in six gem districts or regions (Fig.1, 1, Ametista do Sul, Iraí, Cristal do Sul, Planalto; 2, Quaraí; 3, Lajeado, Soledade, Salto do Jacuí; 4, near Santiago; 5, São Paulo das Missões; and 6, Caxias do Sul). Agate and amethyst are the dominant products; chalcedony (carnelian), onyx, jasper, obsidian and citrine are also found whereas rock-crystal is not exploited. Zeolites, apophyllite, calcite and pyrolusite are exploited as collection pieces (Branco 1997, 1998 a,b; 1999). About 400 extraction sites employing traditional and mechanised equipment are known, but presently most of them are worked out.

2. Piauí Gem Province (PGP)

The province is localised in the eastern border of the Parnaíba Basin in Piauí State (Fig. 1, 17, Pedro II; 18, Buriti dos Montes) and is presently, the single precious opal producing locality in Brazil. The production is mainly concentrated at Pedro II region. The deposits are related to Silurian/Carboniferous sedimentary rocks and Mesozoic basaltic flows. Opal is the main exploited gem in the province. Amethyst, rock-crystal, tourmaline, epidote chalcedony and pink quartz are also found but not in sufficient quantities to make its extraction economic. In addition to the precious opal, the common opal is also exploited for art craft, collections, and laboratory equipment producing industry. Only three out of 38 known exploitation sites have been active in 1997 (Oliveira 1998).

Other Small Scale Gem Producing Regions

Some gem occurrences are reported in the northern Amazonic region. In Amazon State, aquamarine has been found at the vicinities of São Gabriel da Cachoeira Town, in the alluvial deposits of the Curicuriari river (Fig. 1, 56) and vivianite in the Amazon river (57), west of Tupururuquara (Souza, 2000); Amethyst occurrences are localised in granites veins in Alto Rio Negro region, NE of Içana (54) and in Pitinga Village (52). In Pará State there are references to amethyst and rock-crystal at Monte Verde Village (55) and in the Curuá-Maecuru region (51, Collyer 1994). Amethyst is also referred at Rorainópolis in the vicinities of the Perimetral Norte highway (53), Roraima State (Souza 2000).

Production and Reserves

Brazil is the main international producer of coloured gems. The "Instituto Brasileiro de Gemas e Metais Preciosos-IBGM " (Brazilian Institute for Gems and Precious Metals) estimates that about 1/3 of the total coloured gems negotiated in the international markets came from Brazil. Notwithstanding such a large production, the official figures indicate a small Brazilian participation of about 5% of the US$ 1,7 billion of the total international gem commerce. In the last years, the Brazilian production is strongly declining; the extraction has been primarily made by small-scale mining, employing traditional equipment and methods ("garimpos"). Additionally the commerce is based on rough gems, without any kind of fashioning (Netto *et al*. 1998, Lacerda F$^{o.}$ *et al*. 1998, Moraes 1999) and without any official register on the deposits and production. Most of the quarried sites are paralysed or has been
worked out. In 1998 the amethyst production in the RSGP was about 100 ton mostly heated-treated producing citrine, or used as collection pieces; only 2% being cut for gem use. This province is the major Brazilian agate producer (>3,500 ton/year) and also the major world producer of the umbu variety (Branco 1998a, b, 1999). The official registers of the opal production within the PGP in 1997 was 120 kg (Oliveira 1998).

Conclusions

The main Brazilian primary gem deposits are assigned to granitoids-hosted pegmatites, hydrothermal veins and geodes in basaltic flows. Secondary deposits are related to then weathering and re-deposition of the primary occurrences. The Neoproterozoic pegmatites of the Eastern Pegmatitic Province are the major source for the Brazilian gemstones, namely: aquamarine, crisoberyl-kunzite, alexandrite and emerald. The Southern Brazilian Gem Province (Rio Grande do Sul Gem Province) is the major world producer of amethyst and agate from Mesozoic basalts. The Piauí Gem Province produces opals hosted in sedimentary siliciclastic rocks and basaltic flows. The Bahia and Central Gem provinces are major emerald producers. The gems are hosted into biotite phlogopite metamorphosed plutonic ultramafic rocks (schists) of Archean and Paleoproterozoic ages, injected by younger beryl-bearing hydrothermal fluids. Despite Brazil represents one of the major world gem producers and perhaps the largest one, its production does not correspond to its full potential. Many efforts are been made to improve the national production in the next decade.

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