ARCHEAN NUCLEI AND THE DISTRIBUTION OF KIMBERLITE AND RELATED ROCKS IN THE SÃO FRANCISCO CRATON, BRAZIL

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Abstract Available gravimetric data allow defining the low Bouguer gravimetric anomaly associated with the Paleoproterozoic continental plate, which contains the São Francisco Craton. The high anomalies that mark the border of the relative low gravimetric anomaly are related probably to hidden sutures and dense rocks remains formed during sea-floor spreading and deformed later on along Neoproterozoic collisional belts. Kimberlite mineral analyses allied to interpretation of magnetic, geochronological and surface geology data suggest the presence of thick lithosphere below Archean terrains observed in the northern and southern portions of the craton. Important volcanism represented by kimberlite, kamaugite and alkaline intrusive complexes of Early and Late Cretaceous ages is recorded at the south-southwest border of the São Francisco Craton, along the Neoproterozoic Brasília fold belt. Morphostructural and magnetic data suggest that besides the NW-SE structural control of the Alto Paranaíba high, a NE-SW extensional system is associated with igneous intrusions in inner Minas Gerais. Electron microprobe data on minerals from kimberlite sampled in northern and southern São Francisco Craton indicate that they contain temperatures belonging to the diamond stability field were recorded in some specific areas. Recovery of micro- and macrodiamonds confirm the assumption.

Keywords: continental plate, Archean, kimberlite, mineral chemistry, diamond

INTRODUCTION Data processing and interpretation (Zang 1996, Steenkamp 1998) of the South American Gravity Project (Geophysical Exploration Technology-GETECH, University of Leeds, UK) allowed to define the gravimetric low associated with the continental paleoplate containing the São Francisco craton within the South American Bouguer anomaly map. Limits of the plate are defined by Neoproterozoic ensialic rifts, some of which evolved later on to ocean basins. Positive linear gravimetric anomalies that underline the border of the gravimetric low corresponding to the Sanfranciscana plate are probably related to sutures and remnants of dense rocks formed during ocean floor spreading, deformed afterwards during successive collisions (Steenkamp 1998). Individualization of the craton within the continental plate took place during the Brasiliano orogeny, when inversion caused by collision and basin closure gave place to marginal fold belts surrounding the São Francisco foreland (Alkmim *et al.* 1993).

Interpretation of geophysical data from the South American Gravity Project, South American Magnetic Mapping Project, compiled by Patterson Grant and Watson Ltd. of Toronto, Canada, and from COMIG (State Geological Survey of Minas Gerais) allowed to discriminate discrete crust domains, corresponding to the Archean Serrinha and Jequié blocks in the northern portion (Pereira *et al.* 1996), as well as the limit between Paleoproterozoic Mineiro Belt and the southern Archean block (Silva *et al.* 2003). Pressure values above 50 kbar determined in garnet of kimberlite samples from these Archean areas indicate the presence of a thick underlying lithosphere keel (Pereira *et al.* 1996, Pereira and Fuck 2005).

In 1968 De Beers Brazil discovered the first kimberlite within the São Francisco craton at the Santo Inácio River, in the Coromandel area, Minas Gerais. From then onwards, De Beers and other companies have invested continuously in diamond exploration, discovering hundreds of kimberlites and related rocks in Brazil and neighboring countries.

Most of the close to five hundred identified intrusions occur

within the south-southwest sector of the São Francisco Craton, comprising western Minas Gerais and smaller parts of Goiás and São Paulo. A major part of these findings is placed along the Brasília Belt and neighboring areas of the craton eastwards, apparently controlled by northwest-southeast faults related with the development of the Alto Paranaíba high. Main orientation of the fault system is well defined in aeromagnetic surveys covering the region.

North-northeast and northeast structural trends observed in satellite images (Pereira 1990) and also in magnetic data occur in the area. Part of these structures corresponds probably to normal faults associated with a SW-NE extensional system, which reaches the undisturbed Archean terrains in central Minas Gerais.

In the northern sector of the craton there are kimberlite occurrences within the Archean Serrinha and Gavião blocks. Due to their age, exposure of kimberlites within the Gavião block is subject to erosion of younger stratigraphic units, which conform to horst-type structures. Isotopic determinations indicate ages between 75 and 120 Ma for the intrusions in the southern sector, and Proterozoic ages in the northern sector of the craton.

Geochemical studies of minerals in both sectors indicate progressive increase of subcalcic garnet proportions in kimberlites intruded from the border to more central parts of the Archean nuclei not reworked during later orogenies. So far about ten kimberlites in the whole of the São Francisco Craton contain diamond, only one with content justifying economic evaluation.

CONTINENTAL PLATE AND THE SÃO FRANCISCO CRATON

Diachronic fragmentation of the Rodinia supercontinent during the Neoproterozoic, and following collision of resulting blocks during the Brasiliano orogeny, underline the border of the Paleoproterozoic continental plate and the limits of the São Francisco Craton within the plate, respectively. Limits of the Sanfranciscana plate are defined by Neoproterozoic ensialic rifts, which later on evolved to ocean basins. Records of the rift systems that underline the plate border are continental sedimentary deposits

and acid volcanics dated at ca. 1750 Ma (U-Pb, zircon) in the surrounding fold belts and in the foreland (Alkmim *et al.* 1993). Several workers studied crustal features of the craton and marginal fold belts based on gravimetric data (Mota *et al.* 1981, Lesquer *et al.* 1981, Haralyi and Hasui 1982, 1985, Assumpção *et al.* 1984, Ussami 1986, 1993, Ortu 1990, Molina *et al.* 2000). Processing and interpretation of data from the South American Gravity Project allowed to highlight the gravimetric low corresponding to the Paleoproterozoic continental plate which contains the São Francisco Craton (Zang 1996, Steenkamp 1998) in the Bouguer anomaly map of South America (Figs. 1 and 2).

The positive linear anomalies defining the limit of the relative gravimetric low corresponding to the continental plate are related probably with sutures and juvenile material remnants from sea-floor spreading, later on deformed during Neoproterozoic collisional events.

Although the lack of appropriate geological mapping does not allow to compare the whole of the plate border with geological surface features which might be the source of the anomalies, association of some segments of the limit with juvenile materials and suture zones is observed (Pimentel *et al.* 2000, Pedrosa Soares *et al.* 2000, Brito Neves *et al.* 2000, Campos Neto 2000). In eastern Minas Gerais, the limit is represented by thrust fault zones that place the Juiz de Fora complex upon the Mantiqueira Complex, along the Abre Campo discontinuity, and further north upon the Guanhaes block. In the latter case, tectonic slices of ultramafic rocks recording ocean opening and oceanic crust formation were placed along the thrust zone. The chemical and isotopic signature of these rocks is of MORB type, and their estimated Sm-Nd isochron age is 816 ± 72 Ma ($\epsilon_{\text{Nd}} = +4$, Pedrosa Soares *et al.* 1992, 2000). In the Riacho do Pontal belt, the indicated limit coincides with basic metavolcanic rocks of the Monte Orebe/Brejo Seco sequence (Marimon 1990). In the Rio Preto belt, the suggested limit is related probably with rocks of the same composition, presently covered by Paleozoic sedimentary rocks of the Parnaíba Basin. Well-marked gravimetric anomalies are observed along the Brasília belt. The southwest border of the plate is underlined by rather dense high-grade metamorphic rocks from the northern part of the Guaxupé nappe, from where they continue northwestward below the Paraná Basin. In a magneto-telluric profile from the southern São Francisco basement to the Paraná Basin, the high-conductivity anomaly recorded in the western part of the profile was associated with the strong gravimetric gradient marking the plate suture (Padilha *et al.* 2005). At the western border the strong positive gravimetric anomalies suggest that the limit is between the large layered Cana Brava, Niquelândia and Barro Alto complexes and the Goiás magmatic arc. Deep seismic refraction profiles from São Miguel do Araguaia to Posse, across the positive linear gravimetric anomalies, at about $13^{\circ}30'$ south latitude, mantle P wave velocity variations are due to differences between Archean/Paleoproterozoic mantle, which is Fe-depleted and colder (Fig. 3) when compared with the Neoproterozoic mantle below the Goiás magmatic arc (Soares *et al.* 2003, Berrocal *et al.* 2004).

In Almeida's (1977, 1981) proposition, the limits of the São Francisco Craton are represented by important discontinuities and changes of deformation style in the cover. Most of the discontinuities correspond to basement-involved thrust faults that mark the transition from the fold-and-thrust belt to the sub-horizontal cover within the craton. The tectonic significance of these limits were revised and detailed by Alkmim *et al.* (1993). Individualization of the craton within the Paleoproterozoic

continental plate took place during the Brasiliano orogeny, when inversion caused by collision and/or basin closing developed the marginal fold belts that shaped the São Francisco foreland. Therefore, the São Francisco Craton geometry is linked intimately with Paleoproterozoic and Neoproterozoic orogenies. After the first brought together the different Archean crustal segments of the craton, the second, through constructive and destructive lithospheric processes, reworked the paleocontinent margins, shaping them into their present forms (Fig. 3).

PRESERVED ARCHEAN NUCLEI Archean and Paleoproterozoic basement rocks, comprising medium and high-grade metamorphic associations and granite-greenstone terrains, are exposed in the northern and southern sectors of the São Francisco Craton (Teixeira *et al.* 2000, Barbosa & Sabaté 2000). From the geologic and tectonic history of the craton it has been deduced that deformation and amalgamation of the different Archean blocks were the result of Paleoproterozoic orogeny. The relatively stable geotectonic framework, comprising Paleoproterozoic terrains and Archean nuclei, was partially reworked during the Brasiliano orogeny due to the deformation by compression developed in the marginal fold belts. Therefore, polyphase history is common in both sectors of the craton.

Data processing (Zang 1996) and interpretation (Pereira 1996, Pereira & Fuck 2005) of the South American Magnetic Mapping project allowed to discriminating discrete crustal domains in the sub-surface of the northern craton sector, corresponding to the Serrinha and Jequié blocks. Among the images obtained from magnetic data processing, the total magnetic field image (1:1,000,000 scale) offers more information. The magnetic signature allows recognizing limits of the Archean blocks and their nuclei preserved from the Proterozoic orogenies affecting them (Fig. 4).

In the absence of teleseismic studies to defining roots of the Archean blocks identified with gravimetric and magnetic data, geochemical data from xenoliths and xenocrysts incorporated in kimberlite magma work out as proxies to tell about conditions in the lower crust and mantle (O'Reilly and Griffin 1996). Analyses of garnet and clinopyroxene from kimberlites intruded in the Serrinha block indicate that the mantle in this area presented temperatures between 950 and 1200°C and pressure ranging from 34.5 to 55 kbar (Edler and Bizzi 1996). Taking the highest garnet pressure values and corresponding data from clinopyroxene from each kimberlite province, the calculated geothermal gradient at the time of intrusion was between 42 and 45 mW/m, respectively in the central part and at the border of the Serrinha block. The calculated values indicate thicker lithosphere at the center, and thinner lithosphere at block margin, reworked during Proterozoic orogenies. Data integration suggests that the Serrinha block presents a preserved Archean core, whose lithospheric keel represents a favorable environment for diamond preservation. Despite the absence of kimberlite intrusions in the Jequié block, evidence is favorable for core preservation (Fig. 5, 6).

In the southern sector of the São Francisco craton, increasing values of highest minimum garnet pressure from 37 kbar obtained in kimberlite intruding the Brasília belt (Passos Nappe) to 45 and 51 kbar in kimberlite from the Divinópolis-Maravilhas area northeastward indicate transition from a thin lithosphere, typical of mobile belts, to a thick lithosphere of 150 and 200 km (Haggerty 1986), characterizing a preserved Archean core. Figure 7 shows a line of kimberlite intrusions in relation to the limit defined by geophysical data between the Paleoproterozoic Mineiro belt and

the Archean core (Teixeira *et al.* 2000, Silva *et al.* 2003, Pereira & Fuck 2005).

Consistent geochronological data show Archean homogenization, without any evidence of Paleoproterozoic

Figure 1 - Final land gravity distribution (South American Gravity Project 1991) and South American Bouguer anomalies map (Zang 1996).

Figura 2 - Distribution of kimberlite-related rock in the Sanfranciscana continental plate and São Francisco Craton.

Figure 3 - Gravimetric border of the continental plate (Steenkamp 1998) and the São Francisco Craton limit (Alkmim *et al.* 1993) related to geologic map of Brazil.

reworking in the central portion of the basement (Machado & Carneiro 1992, Teixeira *et al.* 2000).

DISTRIBUTION OF KIMBERLITE AND RELATED ROCKS AND GEOLOGICAL ENVIRONMENT

Most kimberlites and related rocks occur at the south-southwest border of the São Francisco Craton, along the Brasília belt, which is the easternmost part of a large orogen developed in central Brazil, between the Amazonian, São Francisco and Paranapanema cratons (Figs. 2, 7). The many units that compose the fold belt, such as Proterozoic sedimentary, metasedimentary and volcano-sedimentary sequences, igneous intrusions, the Goiás magmatic arc, and the Goiás massif, were involved in the tectono-thermal events of the Neoproterozoic Brasiliano orogeny. In general terms, tectonic deformation and metamorphism increase gradually westward, from non-metamorphic sedimentary rocks over the craton in the east, to metamorphic parageneses of amphibolite and granulite facies westward (Pimentel *et al.* 2000, Dardenne 2000). According to Seer (1999), the Araxá, Ibiá and Canastra groups defined by Barbosa *et al.* (1970) and belonging to the southern Brasília belt (Fuck 1994), represent different tectonostratigraphic terrains, apparently without genetic relationship, carried tectonically from different paleogeographic environments. These groups were classified as tectonic slices (Seer *et al.* 2001, 2005): i) Canastra terrane, slice of passive continental margin; ii) Ibiá terrane, slice of volcanic arc sedimentary rocks; iii) Araxá terrane, slice of oceanic crust intruded by collisional granites.

The widespread magmatism recorded by kimberlite, kamafugite, and alkaline complexes in this part of the craton is distributed along a large (300x100-km) NW-SE belt, from the Catalão carbonatite complex in southern Goiás to the upper São Francisco river valley in western Minas Gerais (Fig. 7). Within this belt kamafugites and related alkaline volcanics, which make up the Mata da Corda

Figure 4 - Northern portion of the São Francisco Craton: Serrinha and Jequié archean cratonic blocks and their preserved nuclei.

Formation, constitute a large igneous province, largely outnumbering the known kimberlite pipes (Bizzi *et al.* 1990, Brod *et al.* 2000, Gaspar *et al.* 2003, Read *et al.* 2003). Hundreds of intrusions are concentrated mainly in Coromandel, Romaria and Três Ranchos, along the Mesozoic Alto Paranaíba high. Kimberlite, related rocks, and Cretaceous-Tertiary sediments commonly occur at the Neoproterozoic thrust fronts. Uplift of the Alto Paranaíba high developed listric faults along the surfaces of thrust faults, exercising probably secondary controls on the intrusions, at the same time as sediments were deposited on subsiding blocks (Pereira 1990, Pereira & Fuck 2005).

Kimberlites and related rocks from Coromandel and neighboring areas were dated between 75 and 120 Ma. These ages correspond to different volcanic pulses related with the development of the Alto Paranaíba structural high. Occurrences of conglomerate bearing abundant garnet, spinel, and ilmenite in Coromandel and Romaria, as well as the presence of ventifacts in Coromandel, suggest different origins for conglomerates and the later cover of volcanic sediment of the Mata da Corda Formation. The conglomerates are probably related to erosion of Early Cretaceous kimberlites associated with the initial volcanism of the

Alto Paranaíba high, as is the case of the ca. 120 Ma Canastra 01 (Can 01) diamond-bearing kimberlite, which occurs close to the Cachoeirinha creek, right margin tributary of the São Francisco river in the Canastra ridge (Pereira 1995, Pereira *et al.* 1998). Contrast between mantle signature sampled in Early Cretaceous kimberlites when compared to Late Cretaceous kamafugite (Mata da Corda volcanism) indicates that the lithosphere from the Alto Paranaíba region was heated and re-equilibrated outside the diamond stability field (Figs. 7, 8).

Mineral chemistry data display evidence of distinct Iherzolite garnet windows in Três Ranchos and Coromandel, where pressures vary between 44 and 52 kbar and 49 and 50 kbar, respectively (Skinner 1996). Studies of diamonds from alluvium in these areas (Robinson 1991, Robinson *et al.* 1995) show five localities with different characteristics, which define young, proximal and primary (YPP) sources. Cubic diamonds from populations recorded in Romaria, Três Ranchos (TRS 04 intrusion) and in the São Miguel river (TRS 101, 102, 104) characterize sampling of mantle at the limit of the graphite-diamond stability field, or ca. 44 kbar and 1,000°C (Haggerty 1986) (Figs. 9, 10, 11). This type of diamond is found only within the Araxá terrane (figure 13), where Neoproterozoic

Figure 5 - Northern portion of the São Francisco Craton: Serrinha and Jequé archaic block and their preserved nuclei and kimberlite distribution. Note: the Gavião Block was compiled from geological maps and used to compose the figure.

collisional granites indicate deep crust reworking and probable lithosphere thinning (Bizzi *et al.* 1995). On the other hand, diamond provenance studies in Coromandel and neighboring areas show a unique population of large dodecahedral diamonds from a young, proximal and primary source and absence of cubic diamonds. Despite identification of primary sources that provide diamonds for the São Miguel river diggings (TRS 101, 102, 104) and Vargem Bonita (Can 01) in the São Francisco river, at the extreme SE of the large belt of intrusions, the source of the unique and distinct population of large dodecahedral diamonds from the Santo Inácio, Santo Antônio and Douradinho rivers has not been found (Fig. 13).

Outside the Brasília belt, towards central Minas Gerais, a few intrusions are observed. Apparently distributed along a large belt, extending between the northwestern portion of the exposed basement and the Três Marias area, these kimberlites are related to a NE-SW Mesozoic arch. Evidence of this structure is corroborated by lineaments and magmatic rocks recorded in aeromagnetic surveys, as well as by high topography and remnants of Areado and Mata da Corda formations that appear northeastwards, as far as Januária.

Also the straight valleys of the Abaeté, Borrachudo and Indaia rivers, following apparent normal faults, suggest an extensional system in the area (Pereira 1998, Pereira and Fuck 2005) (Figs. 7, 14).

In the northern sector of the São Francisco craton, the main group of kimberlites occurs in the central part of the Serrinha block. This group comprises several small pipes intruded within the Nordestina granodiorite, considered as syntectonic to the Paleoproterozoic orogeny. The pipes occur along N30W striking faults, the largest one occupying an area of 1.5 hectare. Small dykes appear northwards and westwards of the central province (Figs. 5, 6). The mineral assemblage of the pipes comprises garnet, chrome spinel, clinopyroxene, and rare ilmenite. Grains with chemical signature typical of inclusions in diamonds are common within the spinel population. Phlogopite from one of the kimberlites from the central portion, classified as hypabissal facies diopside-phlogopite kimberlite, was dated by Rb-Sr at 682 ± 20 Ma (Pizani *et al.* 2001). Geothermal gradient of ca. 42 nW/m^2 and microdiamonds recovered from intrusions within the central province, informally

Figure 6 - Serrinha Block - Distribution of garnet pressure in the distinct kimberlitic provinces and diagram $T_{\text{max}} - \text{Cpx}$ (°C) x Garnet - highest minimum pressure ($P_{\text{m inhi}}$).

Figura 7 - Distribution of kimberlite-related rocks in the southern portion of the São Francisco Craton and Mineiro Belt.

Figure 8 - Southeast portion of kimberlite-related rock distribution in Minas Gerais State: interpretation of satellite image and aerial photo.

Figure 9 - Três Ranchos and Coromandel garnet windows.

called Braúna province, indicate the presence of an Archean cratonic core, at whose lithosphere base prevailed conditions favorable for diamond preservation (Pereira *et al.* 1996).

Outcrops of only one pipe with ca. 5 ha and a few small dikes have been found within the Gavião block. Aeromagnetic survey pointed out additional anomalies northwestward of these intrusions. Drilling recorded kimberlite at depths of 246 m and 159 m in two of these anomalies, ca. 27 km northwest of the outcropping intrusions. Drill cores record metamorphic kimberlite of crater facies, in both cases emplaced at the base of Morro do Chapéu Formation

quartzite, therefore intruding the underlying Caboclo and Tombador formations of the Chapada Diamantina Group. These findings indicate that these intrusions are younger than the primary sources required for the diamonds of conglomerates of the Tombador Formation. The kimberlites within the Gavião Block occur west-southwest from Barra do Mendes, Bahia, along the area of influence of the Barra do Mendes-João Correia lineament, which divides the eastern and western structural domains of the Chapada Diamantina (Uhlein and Chaves 2001). Regionally the area of kimberlite occurrences is within the Chapada Diamantina (Diamondiferous Plateau, in a literal translation), origin and evolution of which is related with the development of the Espinhaço rift in Bahia (Figs.

Figure 10 - Três Ranchos and Coromandel garnet windows. Modified from Skinner (1996).

Figure 11 - Diagram Tmax - Cpx(ToC) x garnet - highest minimum pressure (Pminhi) of Coromandel and Três Ranchos areas. Modified from Skinner (1996).

Figura 12 - The Araxá Group and localities with unique young primary and proximal (YPP) diamond source containing cube diamonds.

Figura 13 - Occurrence of unique large and dodecahedral diamond population of the Coromandel area.

South portion of the São Francisco Craton
Aeromagnetic cover: total magnetic field

Gravimetric border of the continental paleoproterozoic plate (Steenkamp, 1998)
Border of the São Francisco Craton (Alkmim et al., 1993)
Mesozoic deposits :
Mata da Corda Formation
Areado Formation
Magnetic lineament
Magnetic anomaly
Kimberlite

Figure 14 - Southern portion of the São Francisco Craton: northwest-southeast and southwest-northeast magnetic lineaments, magmatism and distribution of the Areado and MATA da Corda cretaceous deposits.

Figure 15 - Gavião Block: interpretation of satellite image and kimberlite occurrences.

Figure 16 - Photo 1 - Kimberlite outcrop in the Gavião Block. Photo 2 - Detail of the kimberlite folded by the Brasiliano Cycle.

5, 15). Rocks composing the Espinhaço Group in the area are included in the Rio dos Remédios, Paraguaçu and Chapada Diamantina groups. The Chapada Diamantina Group, comprising the Tombador, Caboclo and Morro do Chapéu formations, is the upper unit of the Espinhaço Group. Ages obtained from base to top of the units included in the supergroup indicate Paleoproterozoic evolution for the ensialic rift/basin formed within the São Francisco craton basement rocks (Schobbenhaus et al. 1994, Babinski et al. 1993, 1999).

The outcropping kimberlite occurs as a blow along the NW-SE strike slip fault. Outcrops are of folded talc schist, and observed fold axes display the same strike as regional folding (Williamson and Pereira 1991). Petrography and mineralogical analyses of concentrates describe the intrusion as phlogopite kimberlite of hypabissal facies, metamorphosed under low-grade conditions and altered to talc, quartz and chlorite. Spinel and rare diamond are mineral indicators of the intrusion. Rb-Sr age determination of phlogopite from a drill core sample resulted in 1152 Ma for the kimberlite (Williamson and Pereira 1991). Interpretation of aerial photographs and field work suggest that intrusion of this kimberlite took place during Tombador Formation conglomerate deposition and that kimberlite intrusions of similar age were the source of diamonds found in these conglomerates (Fig. 16).

CONCLUSIONS Processing and interpretation of regional gravimetric and aeromagnetic data from the South American Gravity Project and South American Magnetic Mapping Project allowed to trace the limits of a former Paleoproterozoic continental plate, which contains the present São Francisco craton. The limits suggested by gravity data are associated in part with suture zones and with the occurrence of juvenile rocks recorded within the Brasiliano fold belts that surround the craton. In the deep seismic refraction profile performed across northern Goiás, central Brazil, at about latitude 13°30' S, P wave velocity of 8.0 km/s and 8.25 km/s in the mantle westward and eastward from the large positive gravity anomaly, respectively, record the western border of the continental plate (Soares et al. 2003, Berrocal et al. 2004). The velocity change marks the limit between hotter and denser Neoproterozoic mantle below the Goiás Magmatic Arc and colder, depleted, refractory mantle below the Paleoproterozoic continental plate. Similarly, at the southwestern limit, Padilha et al. (2005) associate the isolated high conductivity anomaly in their magnetotelluric profile with the strong gravimetric gradient, recording the plate suture below the Phanerozoic Paraná Basin deposits (Figs. 2, 3).

Integration of geophysical data with surface geology and geochronology in the northern sector of the craton allowed to defining the limits of the Archean Serrinha and Jequié blocks, as well as their cores not affected by Proterozoic orogenies. Chemical data of minerals from kimberlites intruded into the Serrinha block indicate that at the time of intrusion the temperature of the mantle was probably between 950°C and 1,200°C, whereas pressure values of garnet are between 55 and 34.5 kbar. Comparison of highest garnet pressure values with data from corresponding clinopyroxene data recovered from kimberlite samples from the various provinces identified within the Serrinha block indicate geothermal gradients between approximately 42 and 45 mW/m² in the central part of the block and at its borders, respectively. Available data suggest a preserved Archean core in the Serrinha block, with a lithospheric keel that at its base presents conditions favoring preservation of diamond (Fig. 4, 5, 6).

To the south of the craton, increasing in garnet between 37

kbar observed in kimberlite intruded within the Brasília Belt, to 45 and 51 kbar in intrusions within the Archean basement rocks of Divinópolis-Maravilhas records the transition from relatively thin lithosphere, characteristic of reworked areas, to thick lithosphere, typical of preserved Archean cores, favoring crystallization and preservation of diamond at its base (Fig. 7).

In the south-southwest of Minas Gerais, where most kimberlite intrusions and related rocks are concentrated, chemical data of garnet recovered in samples from alluvial deposits indicate concentration areas generally correlated with intrusions placed upstream from the sampling site. Comparison between chemical data and garnet highest minimum pressure paragenesis and temperature of clinopyroxene led to identification of highly interesting garnet windows in Três Ranchos and Coromandel, defined by kimberlites TRS 04, 101, 102, 104 and SCL 01, 06, SRA 04, DEL 07, DDO 04, 06. Presence of diamond in cubic form in populations from Romaria, Estrela do Sul, Três Ranchos and São Miguel river, characteristic of mantle sampled at the limit of the graphite-diamond stability fields, that is 44 kbar and 1,000°C for 40 mW/m², is confirmed in the Três Ranchos intrusions TRS 04, 101, 102 and 104. These populations, which suggest similar mantle sampling or geotherm, appear to the west of Coromandel, in the Araxá Group terrane domain, where Neoproterozoic collisional granites indicate deeper crust reworking and probable lithosphere thinning. In the Coromandel window, bulk samples of kimberlite have not revealed the presence of diamond, despite the evidence of several intrusions having shown sampling of mantle within the stability field of diamond (Skinner 1996) (Figs. 9, 10, 11, 12).

The Canastra 01 (CAN 01), Três Ranchos 04 (TRS 04) and X270 kimberlites, the latter exposed between Lagoa Formosa and Carmo do Paranaíba (Read et al. 2003) were dated at 120, 95 and 89.5±3.4 Ma, respectively. This demonstrates that the concept that the initial Early Crataceous volcanism in the Alto Paranaíba region was kimberlitic in nature and that the final Late Cretaceous volcanism was kamafigitic can not be held as an absolute rule. The Santa Rosa 04 kimberlite (SRA 04) from the Coromandel area, which apparently sampled mantle within the diamond stability field, has a Rb-Sr mica age of ca. 83 Ma (Skinner 1996). Proximity of true kimberlite, including diamond-bearing kimberlite, kamafigite and carbonatite suggests complex evolution of the mantle in the Alto Paranaíba region (Figs. 9, 10, 11).

Kimberlite intrusions from more internal sectors of the São Francisco Craton in Minas Gerais sampled apparently preserved lithosphere. Despite the young age of ca. 81 Ma, one of the kimberlite intrusions close to Maravilhas bears diamond and pressures of garnet are above 50 kbar (Fig. 7).

Comparison of highest values of minimum pressure (P_{minhi}) of garnet and corresponding clinopyroxene data from the various kimberlite provinces identified within the Serrinha block show variations between ca. 42 mW/m² at the core and 45 mW/m² at the border of this block. Several kimberlite pipes from the central province, one of which was dated at 682±20 Ma, bear microdiamonds (Fig. 6).

The determined phlogopite Rb-Sr age of c. 1152 Ma from the outcropping kimberlite within the Gavião block, as well as field relations, place the intrusion as coeval with deposition of Tombador Formation conglomerate. On the other hand, younger kimberlites, below sand-conglomerate deposits of the Morro do Chapéu Formation, have been recorded also. In this case possibly similar intrusions constitute the source of diamonds found in the locally diamond-bearing conglomerate of the Morro do Chapéu Formation.

Integration of geotectonic units defined in the São Francisco Craton with chemical data from kimberlite minerals, diamond provenance studies, geochronology and field relations allow to conclude: i) in the Alto Paranaíba region the Early Cretaceous kimberlites present greater potential for diamonds than the Late Cretaceous kimberlites; ii) within the Archean core of the São Francisco Craton, in the Quadrilátero Ferrífero and neighboring

areas, in Minas Gerais, Early and Late Cretaceous kimberlite present the same diamond potential; iii) exposure of kimberlite within the Gavião block is favored by horst-type structures, allowing for erosion of younger than Mesoproterozoic units.

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