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Discovery of the first kimberlitic pipes at Borborema Province, NE Brazil

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Abstract

Two new kimberlitic pipes were discovered in the northern portion of Rio Grande do Norte state during fieldworks developed into the Diamond Brazil Project. The intrusions were named as Santa Fé-1 and Santa Fé-2 and are located in the Rio Piranhas-Seridó domain, Borborema Province. Santa Fé-1 and Santa Fé-2 pipes have areas of 27 ha and 9 ha, respectively, and exhibit a volcaniclastic kimberlite breccia texture containing ilmenite, garnet, spinel and clinopyroxene in abundance. Eclogite garnet contains Na2O > 0.07 wt. % and has been classified as G3"D" and G4"D". According to ground magnetic and gravity survey data, the kimberlitic intrusions are cylindrical bodies, magnetically stratified and discordantly hosted into highly magnetic and dense rocks, which correspond to granodioritic and tonalitic orthogneisses and migmatites of the Arabia Complex (2546 ± 4.2 Ma, SHRIMP U-Pb zircon). The recognition of kimberlitic pipes with expressive dimensions in an off-craton setting opens new horizons to the exploration of primary sources for diamonds in the Borborema Province and especially in the Rio Grande do Norte state.

Keywords: Discovery, Kimberlite, Borborema Province, Diamond Brazil Project.

INTRODUCTION

Kimberlite pipes discoveries were made by the Department of Mineral Resources (DEREM) of CPRM during the Diamond Brazil Project, which is part of the program Evaluation of Mineral Resources of Brazil, linked to the "Strategic Management of Geology, Mining and Mineral Transformation" major program and sponsored by the Growth Acceleration Program (PAC 2). The fieldworks resulted in the discovery of pipes of probable kimberlitic composition at Pedro Avelino municipality, central portion of Rio Grande do Norte State, NE Brazil (Figure 1).

The pipes (henceforth kimberlite pipes), were named as Santa Fé-1 and Santa Fé-2, are inserted in the Lages sheet (SB.24-X-D-VI) and have UTM coordinates 796226E / 9380706S and 795662E / 9385226S, respectively, Datum WGS-84, zone 24 South. The discovery of the Santa Fé-1 pipe confirmed the previous hypothesis of Silveira (2006), who recognized kimberlite pathfinder minerals and peridotite and eclogite xenoliths nearby the newly discovered intrusion. The Santa Fé-2 pipe corresponds to a completely newly occurrence, never reported before.

TECTONIC-GEOLOGICAL SETTING

The Santa Fé-1 and Santa Fé-2 intrusions are located in the Rio Piranhas-Seridó domain (DPS) (Angelim et al. 2007; Medeiros et al. 2010) of the Bor-

borema Province (Almeida et al. 1977), nearby the central-south boundary of the Potiguar basin (Figure 1). The DPS consists predominantly of Paleoproterozoic gneissic-migmatitic basement rocks (Arábia, Caicó and Santa Cruz Complexes) and Neoproterozoic supracrustal rocks (Seridó Belt), both intruded by Brasiliano-age granitoids.

Mesozoic-Cenozoic volcanism occurs regionally and is associated to three distinct magmatic events, defined by $^{40}Ar/^{39}Ar$ dating of plagioclases: Ceará-Mirim (132 ± 1 Ma, Souza et al. 2003); Serra do Cuó (93.1 ± 0.8 Ma, Souza et al. 2003); and Macau (70-65 Ma and 9-6 Ma, Souza et al. 2003; Silveira 2006; Pessoa Neto et al. 2007).

The Santa Fé-1 and Santa Fé-2 bodies are hosted by granodioritic to tonalitic orthogneisses and migmatites of the Arábia Complex (2456 ± 4.2 Ma, SHRIMP U-Pb zircon, Costa & Dantas 2014) and overlaid by olivine basalts of the Macau Formation (Figure 2). A Sm-Nd isochron using garnet from heavy minerals concentrate and whole-rock xenoliths of peridotites yielded an age of 69.7 ± 8.6 Ma (Silveira 2006), which is coeval with the Macau magmatism.

THE KIMBERLITIC INTRUSIONS

The Santa Fé-1 and Santa Fé-2 kimberlitic intrusions are sub outcropping (depth < 0.5 m), pipe-shaped, with negative relief generating semicircular lagoons, with 27 ha and 9 ha dimensions, respectively, representing the upper portion of the pipes. The Santa Fé-2 pipe, in particular, shows brown-reddish residual top soil and an anomalous concentration of wild pinion-type vegetation.

Both bodies are similar in composition and texture, being described as highly weathered, brownish green to whitish volcaniclastic kimberlite breccias (crater facies). The distinctive inequigranular texture is characterized by a macrocrystal (> 1 mm) assembly of olivine, chromite, pyrope garnet, picroilmenite and Cr-diopside disposed in a fine-grained matrix. The matrix shows whitish green color and is composed predominantly of olivine (pseudomorphs), serpentine and carbonate.

The chromite grains, analyzed by electronic microprobe, are classified as kimberlitic spinel (Cr--spinel). Cr-diopside occurs as angular grains with sculptured surface. Pyrope garnet occurs as angular grains showing remaining kelyphitic to sub-kelyphitic and sculptured surfaces, being violet, orange or red in color. Grains larger than 0.5 cm are common and may be easily distinguished without magnifying lens. The more common xenoliths found in both intrusions are biotite gneisses (wall rock), eclogites and garnet peridotites, along with deep facies autoliths (hypabyssal). Carbonatization occurs as veinlets and disseminations in the matrix (Figures 3 A, 3B).

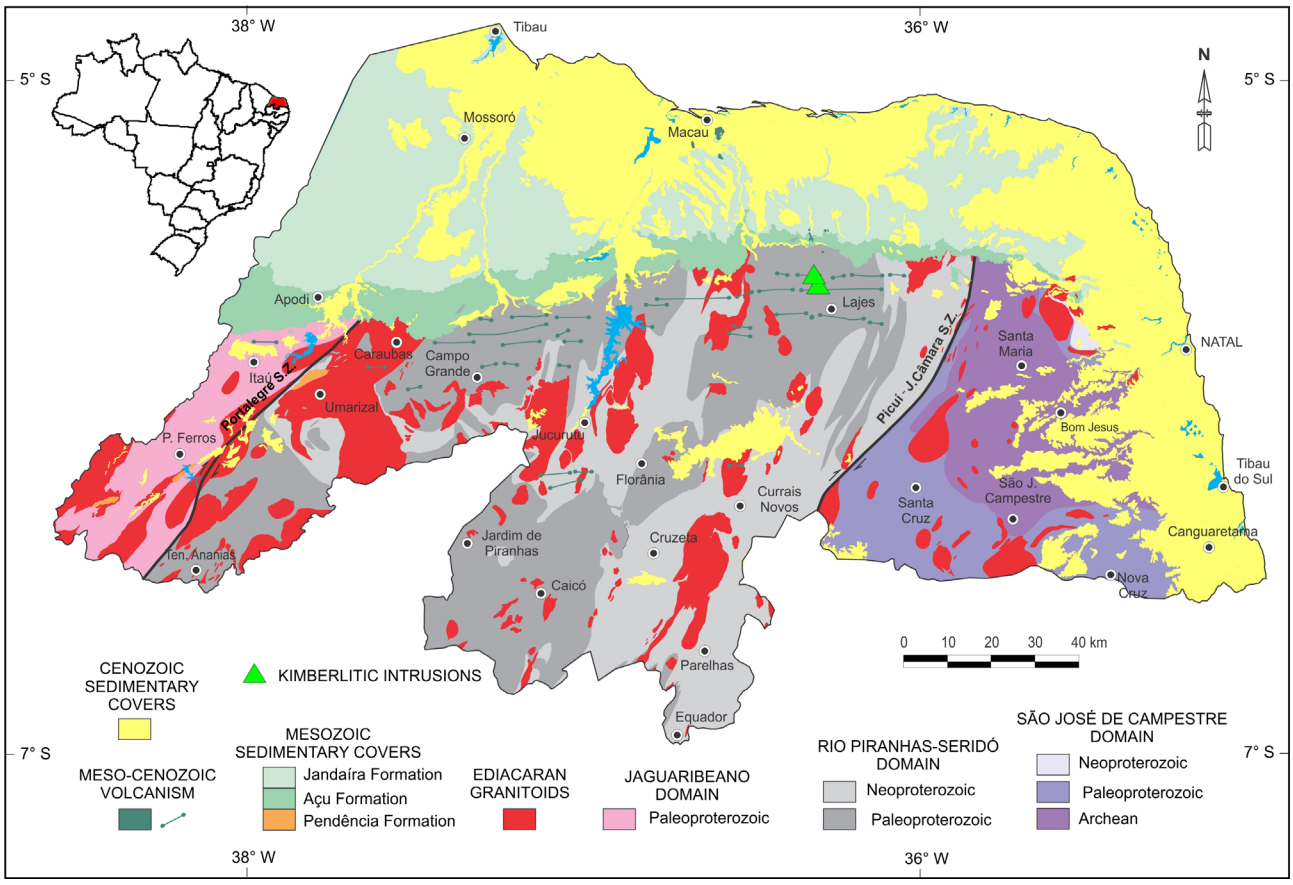

Figure 1: *Simplified geological map of Rio Grande do Norte State, Brazil (Medeiros et al. 2010) with location of Santa Fé-1 and Santa Fé-2 kimberlite intrusions.*

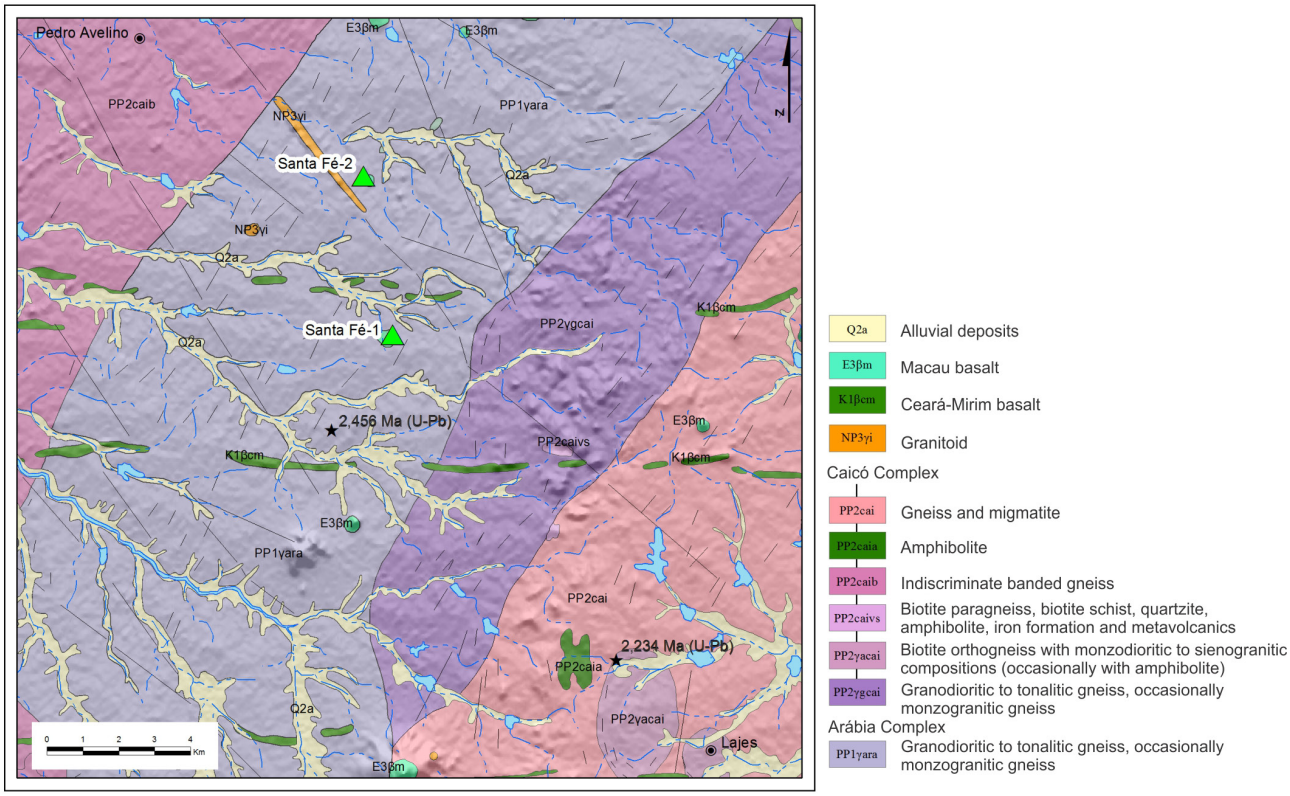

Figure 2: *Detailed geological map (Costa & Dantas 2014) of the region where Santa Fé-1 and Santa Fé-2 kimberlitic intrusions are located.*

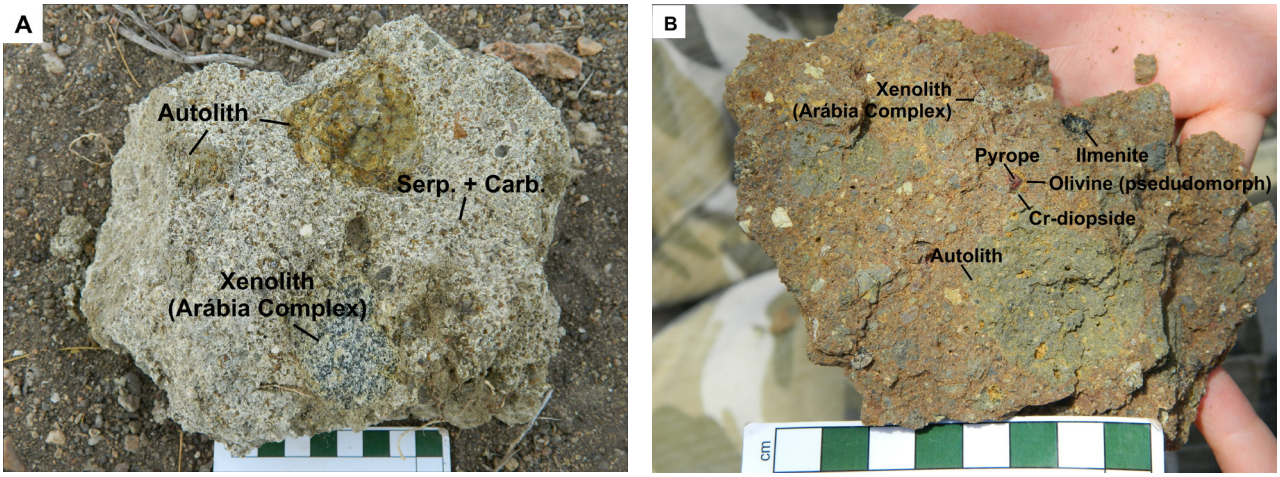

Figure 3: *Santa Fé-1 (A) and Santa Fé-2 (B) samples, characterized as volcaniclastic kimberlite breccias, highly weathered and rich in xenoliths and kimberlite indicator minerals.*

MINERAL CHEMISTRY OF MANTLE GARNETS

Chemical analyses by electronic microprobe revealed that the garnets of Santa Fé-1 and Santa Fé-2 intrusions have compositions corresponding to pyrope, predominantly, and almandine, subordinately, with variable CaO and Cr_2O_3 grades (Table 1), which plot predominantly on the G1, G3, and G4 fields, being compatible with high-Ti megacrystals, eclogites, and garnet pyroxenites, respectively (Figure 4).

Although neither of the analytical results from these kimberlitic intrusions plot on the harzburgitic garnet field (G10 Cr-rich and Ca-poor garnets), 41 eclogitic garnets of the Santa Fé-1 pipe and six of the Santa Fé-2 pipe show Na_2O > 0.07%, being hereby classified as G3"D" or G4"D". Such groups are indicative of strong P-T and composition association with diamonds (Grutter et al. 2004). The garnets of Santa Fé-1 pipe, which have Cr_2O_3 grades less than 0.75%, plot on the field of inclusions in diamonds, while the Santa Fé-2 pipe garnets are Na_2O- and TiO_2-poor (Figure 5).

GEOPHYSICS

Magnetometric Signature

According to a ground magnetometric survey carried out by Silveira (2006) at the target where CPRM later discovered the Santa Fé-1 pipe and by

CPRM at Santa Fé-2 pipe, both are cylindrical in shape, magnetically stratified and discordantly intruded in rocks with high magnetic susceptibility (Figure 6). The kimberlite pipe portion closer to the surface, named yellowground, is more weathered and shows lower magnetic susceptibility, while the deeper, less weathered rocks (blueground) are more magnetic.

In the regional magnetometric context, the Santa Fé-1 and Santa Fé-2 pipes show low magnetic contrast with the host rocks of Arábia Complex, and are practically imperceptible even on the 500 meter spaced-lines airborne maps.

Ground Gravity Signature

The Santa Fé-2 kimberlite pipe was detailed with a ground gravity survey, and the results revealed a semicircular shape body with ~200 meters in diameter at subsurface (blueground), characterized by negative density in relation to wall rocks (Figure 7), with a pattern similar to other known kimberlitic bodies (Isles & Moody 2004).

Table 1*: Chemical composition of Santa Fé-1 and Santa Fé-2 garnets. Values in percentage. *Data for Santa Fé-1 obtained from heavy minerals concentrates nearby the pipes, as in Silveira (2006).*

	Santa Fé-1*	**Santa Fé-2**
Na_2O	0 - 0.30	0 - 0.08
MgO	2.79 - 22.85	2.81 - 22.95
SiO_2	35.68 - 44.04	36.94 - 44.15
Al_2O_3	19.65 - 24.96	19.38 - 24.44
CaO	1.01 - 11.89	1.04 - 6.04
Cr_2O_3	0 - 2.58	0 - 1.61
TiO_2	0 - 0.75	0 - 0.60
NiO	0 - 0.136	0 - 0.121
FeO	4.96 - 31.49	6.09 - 30.32
MnO	0.07 - 1.86	0.12 - 6.73
K_2O	0 - 0.028	0.039 - 0.748
Total	**98.07 - 102**	**100 - 102**
Almandine	5.80 - 67.81	3.70 - 69.04
Grossular	2.72 - 27.70	3.03 - 15.34
Pyrope	10.88 - 75.50	11.84 - 76.27
Spessartine	0.13 - 4.04	0.24 - 16.10
Knorringite	0 - 3.77	0 - 2.31
Uvarovite	0 - 0.78	0 - 0.41

FINAL REMARKS

The kimberlitic nature of the Santa Fé-1 and Santa Fé-2 pipes was defined based on: i) kimberlitic paragenesis; ii) mineral chemistry; iii) typical inequigranular texture; iv) semicircular shape; v) magnetometric and gravity data compatible with known kimberlitic intrusions; and vi) presence of mantle xenoliths.

Therefore, it can be said that such intrusions, representing kimberlite pipes of crater facies with relatively large surface areas, are the first (and unique, up to now) kimberlitic pipes reported from Borborema Province.

Considering that, in general, kimberlite pipes occur as clusters, placed on intersections of deep structures, it is possible that other similar intrusions can occur in the region.

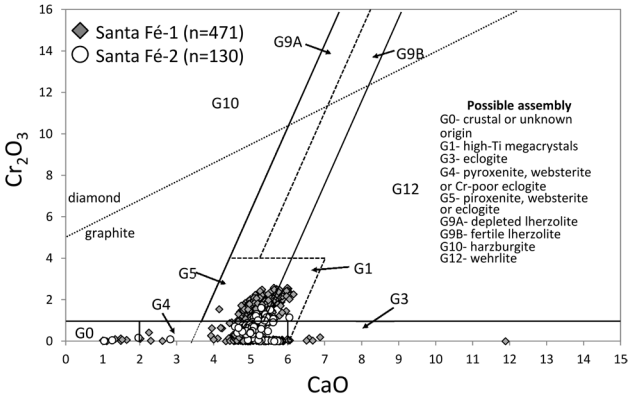

*Figure 4: CaO versus Cr2O3 (wt %) diagram for mantle garnets classification, according to the methodology proposed by Grutter et al. (2004). *Chemistry data for Santa Fé-1 obtained from heavy minerals concentrates nearby the pipes, as in Silveira (2006).*

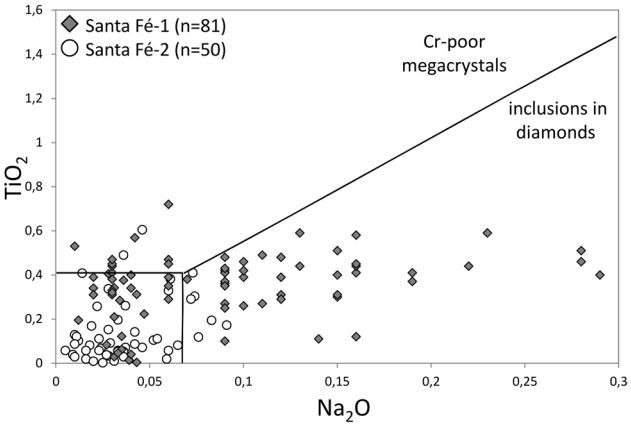

Figure 5*: Na_2O versus TiO_2 (wt %) diagram, as proposed by Cookenboo & Grutter (2007) for garnets with Cr_2O_3 grade < 0.75%. *Chemistry data for Santa Fé-1 obtained from heavy minerals concentrates nearby the pipes, as in Silveira (2006).*

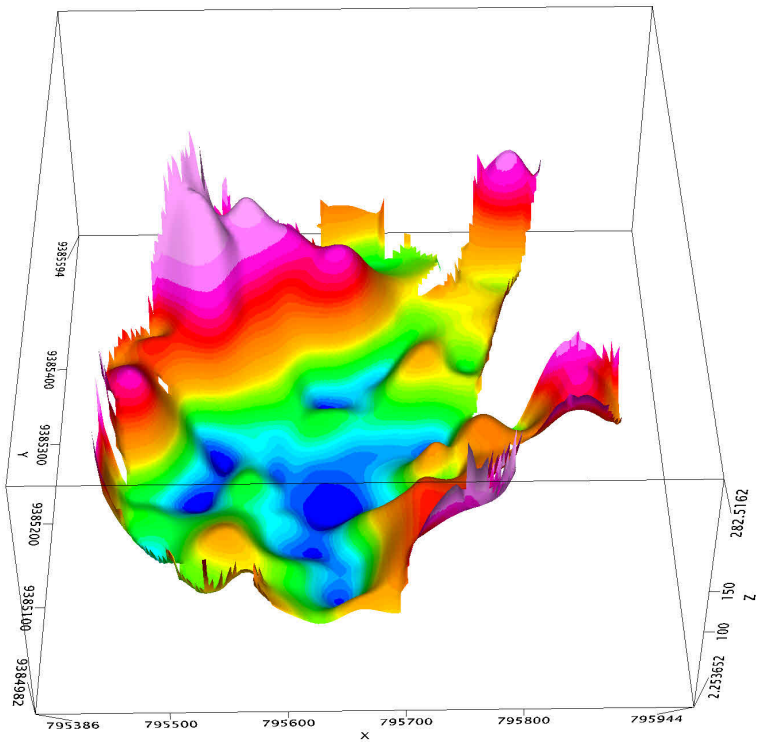

Figure 6*: 3D view of the regional component of the total magnetic field reduced to the pole for Santa Fé-2 pipe, semicircular in shape. The high susceptibility of the host rocks results, in the reduced to the pole map, a negative signature for the intrusion.*

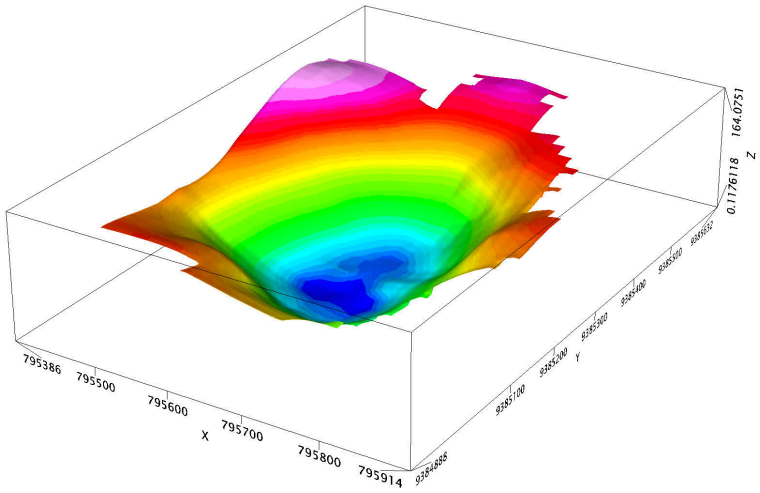

Figure 7*: 3D view of the gravity anomaly at Santa Fé-2 intrusion. The circular negative anomaly has amplitude and shape characteristic of kimberlitic pipes.*

The mineral chemistry of eclogitic garnets classified as G3"D" or G4"D" and its association with eclogitic xenoliths is a positive factor that should be considered by companies interested in exploring the diamondiferous potential of the Santa Fé-1 and Santa Fé-2 intrusions, since kimberlitic bodies with eclogite xenoliths are likely to contain E-type diamonds.

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