Anuário do Instituto de Geociências
Universidade Federal do Rio de Janeiro
https://revistas.ufrj.br/index.php/aigeo/

ISSN 0101-9759
e-ISSN 1982-3908

Gemology and Geochemistry of Staurolites from the Casa Nova Region, Brazil

Gemologia e Geoquímica de Estaurolitas da Região de Casa Nova, Brasil

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Abstract

The properties of minerals used as gemstones could help or even reveal new aspects about the geological evolution of the region where a mineral was found. The objective of this study was the gemological characterization and acquisition of chemical data on staurolites from the city of Casa Nova (Bahia, Brazil). The gemological data are within the normal range for the staurolite mineral, except for the absence of pleochroism, above-average densities in two specimens, and a rare color (intense red) in a sample. The intrinsic part of these gems is in possible correlations involving their properties, such as: color, refractive index, birefringence, relative density, and the amounts of FeO in the samples. The geochemistry of these samples is unusual; FeO and MgO appear in considerably above-average quantities, and Al_2O_3 is up to 8% below average; the presence of CaO is also rare. Therefore, staurolites from Casa Nova (Bahia) have the potential to be used as gemstones, and their geochemistry combined with the gemology of these samples is a great indication for further studies.

Keywords: Gemological properties; Bahia; Gems

Resumo

As propriedades dos minerais utilizados como gemas podem ajudar ou mesmo revelar novos aspectos sobre a evolução geológica da região onde um mineral foi encontrado. O objetivo deste estudo foi a caracterização gemológica e a obtenção de dados químicos sobre as estaurolitas do município de Casa Nova (Bahia, Brasil). Os dados gemológicos estão dentro da faixa normal para o mineral estaurolita, exceto pela ausência de pleocroísmo, densidades acima da média em dois espécimes e uma cor rara (vermelho intenso) em uma amostra. A parte intrínseca dessas gemas está em possíveis correlações envolvendo suas propriedades, tais como: cor, índice de refração, birrefringência, densidade relativa e quantidades de FeO nas amostras. A geoquímica dessas amostras é incomum; FeO e MgO aparecem em quantidades consideravelmente acima da média, e Al_2O_3 está até 8% abaixo da média, a presença de CaO também é rara. Portanto, os estaurolitas de Casa Nova (Bahia) têm potencial para serem utilizados como gemas, e sua geoquímica combinada com a gemologia dessas amostras é uma ótima indicação para novos estudos.

Palavras-chave: Propriedades gemológicas; Bahia; Gemas

Received: April 5, 2024; Accepted: May 7, 2024

1 Introduction

Since the end of the 20th century, it has become customary for countries to catalog and disclose the properties of their gems for numerous purposes, whether marketing, academic or criminal. Globally, gemological studies do not cease, and these data are frequently updated. For example, for staurolites, which in recent years had a good deal of information, new occurrences were discovered and already characterized (Arem 2024). However, in Brazil, there is a gap in this aspect, where many of the gemological properties are unknown, nor are the existing ones disclosed, even in regions that have already had a relevant production of gemstones. Brazil is a significant gemological province and, paradoxically, Brazilian scientific gemology is still embryonic (Barbosa 2020).

The staurolite crystallizes in the monoclinic system. They have the chemical formula $Fe_2Al_9Si_4O_{23}(OH)$. The color of this mineral could be dark brown, reddish brown, orange-red, yellowish brown, brownish black. Staurolite crystals in opaque cross shapes are popular gemstones. However, this material is very rarely transparent or facetable. These dark colored gems would make very durable jewelry pieces. Staurolites can form as twinned crystals at either 60° or 90°, creating interesting natural cruciform pieces. Thus, these stones are popularly called "fairy crosses" or "fairy stones". Staurolite crystals with both 60° and 90° twinning are extremely rare. As natural or polished cross-shaped crystals in raw stone jewelry designs, staurolites are very popular. With a hardness of 7-7.5, they make very durable jewelry stones, especially as pendants. However, such gems are rarely transparent, always small, dark in color, and lack fire or dispersion. Staurolites are silicates (containing aluminum and other metals), belong to the group nesosilicates. Staurolite is a mineral product of medium-grade regional metamorphism processes in aluminum-rich rocks and, therefore, is commonly found in schists and gneisses. It is associated, as can be assumed, with minerals of similar occurrence such as garnet and kyanite. It is commonly used as a mineral index of the degree of metamorphism of a rock, as an indicator of the average degree. (Skerl & Bannister 1934) (Anderson 1984) (Roberts et al. 1990) (Mazdab 2001) (IBGM & Gama 2009) (Deer et al. 2010) (Klein & Dutrow 2012) (Bonewitz 2013) (Schumann 2020) (Arem 2024).

In Brazil, studies on staurolites are very rare, such as the work done by Kuyumjiam (1998). In other studies using Brazilian staurolites, these minerals remain in the background, not being the object of study, but a tool, something complementary or a consequence of the findings of the main research.

Then, in this paper we investigated the gemological characteristics of the three staurolites from the city of Casa Nova, State of Bahia, Brazil, extracted by the company F G Mineração LTDA. Furthermore, we realized studies with the chemical properties. The gemological characterization combined with geochemistry could also aim to identify the mineral's provenance for commercial valorization (directly interfering with the economic value, as in the case of Burmese rubies and sapphires from Cashmere) as well as for cases of investigation and criminal expertise; in Brazil, this paper has more value due to the lack of specific studies on Brazilian staurolites. Art. 655 of the Brazilian Civil Code establishes that banks and government agencies accept cut gemstones in pledge if a debt is collected in court; under Brazilian law, jewelry has as much value as gold (Brazil 2002).

1.1 Location

The area of the municipality of Casa Nova (Figure 1B) comprises approximately 9,657.51 km², making it one of the largest territories in the state of Bahia. It is located in the mesoregion of the São Francisco da Bahia Valley and in the microregion of Juazeiro Bahia. Casa Nova is limited to the municipalities of Sobradinho, Sento Sé, Remanso, Petrolina (PE), Afrânio (PE) and Dom Inocêncio (PI).

2 Regional Geological Context

The municipality of Casa Nova (Figure 1A) is located in the extreme northwest of Bahia, with a total area of 9,658km², in the Médio São Francisco region. The Municipality of Casa Nova comprises lithotypes belonging to the Riacho do Pontal fold belt (Casa Nova group) and the São Francisco craton consisting of lithotypes representing the Sobradinho-Remanso complex, Lagoa do Alegre complex, Rio Salitre greenstone belt and Colomi group (Vieira 2005).

Surface Cenozoic covers are characterized in the area, mainly by continental aeolian deposits made up of sandy matrix sediments that form paleodunes (Diniz & De Lima 2008).

In the study area (Figure 1A), the Riacho do Pontal Range is represented by the Casa Nova Group, composed of the Barra Bonita and Mandacaru formations, characterizing the Casa Nova Nappes System (Caxito & Uhlein 2013). The Barra Bonita Formation is composed of biotite schist, marble and quartzite, interpreted as deposited in a marine platform environment. (UHLEIN et al. 2013). The Mandacaru Formation, in turn, is represented by garnet-

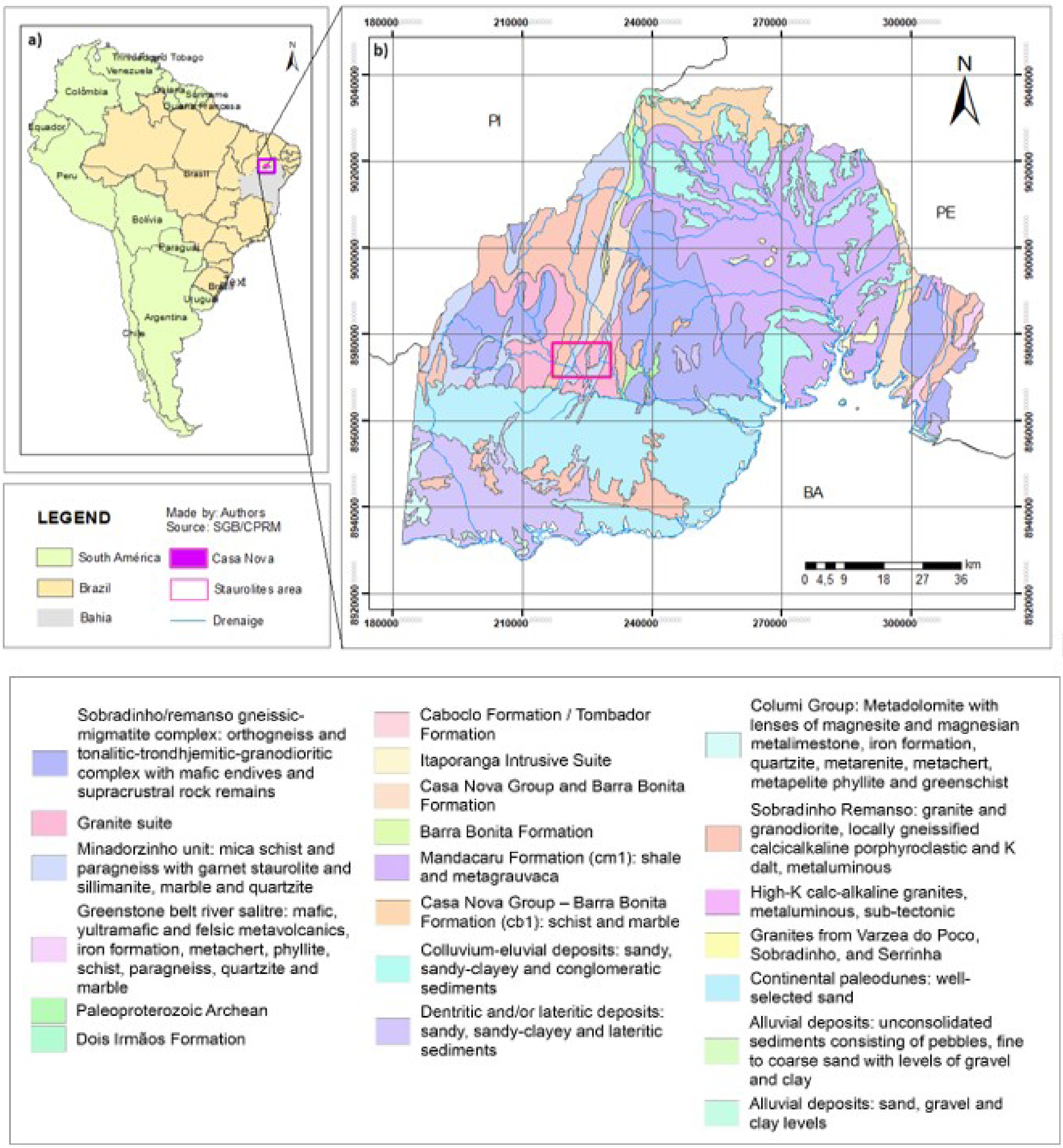

Figure 1 A. Location of the Casa Nova region in the South America map; B. Geological map of the municipality of Casa Nova with the location of the area of provenance of the staurolite crystals analyzed in this work.

mica schist, metagraucava levels and centimeter to meter horizons of marble where the staurolites, objects of this research, are found (CPRM 2014).

The Archean basement of the area is represented by the rocks of the Sobradinho-Remanso, Lagoa do Alegre and Rio Salitre complexes. The Sobradinho-Remanso Complex, a basal unit, is formed by migmatite orthogneisses of tonalitic to granodioritic composition.

Sequences of the greenstone belt type belonging to the Lagoa do Alegre and Rio Salitre complexes occur covering the basement rocks. The complexes are mainly made up of banded iron formations (BIF) associated with metamafic-metaultramafic schists, paragneisses and feldspathic quartzites (CPRM 2014).

The basement rocks are intruded by the Juazeiro-Lagoa do Alegre Suite, also of Archean age, characterized by migmatite orthogneiss, with granitic to tonalitic and basement rock enclaves. During the Trans-Amazonian Cycle, granite bodies from the Fazenda Forte Suite, with compositions varying from monzogranite to syenogranite, intruded into the basement. These bodies are generally formed by fine- to medium-grained rocks and have enclaves of basement rocks (Brito Neves & Cordani, 2013) (CPRM 2014).

3 Material and Methods

Three staurolites crystals were randomly selected (Figure 2) from Casa Nova, in the State of Bahia (Brazil). The minerals were obtained in their raw state and later were cut. Additionally, a color table employed by the trade that has 384 colors and hexadecimal codes (DevMedia 2013) was used to classify the mineral's color. The work method applied for the gemological characterization carried out on the gems of the Casa Nova (Bahia) included the use of classic instruments of gemological analysis, including the hydrostatic balance, dichroscope, spectroscope, ultraviolet lamp, microscope gemological, polariscope and refractometer. To identify the composition and chemical contents of the samples, we used Electron Dispersive spectroscopy (EDS) on a Scanning Electronic Microscope (SEM-EDS).

3.1 Refractometer

We employed a Rayner Dialdex refractometer with attached light source (monochromatic filter included) to determine the birefringence, character and optical signal of the investigated gemstones. We made six readings to guarantee maximum precision according the procedure described by Anderson (1984). Furthermore, a quartz (rock

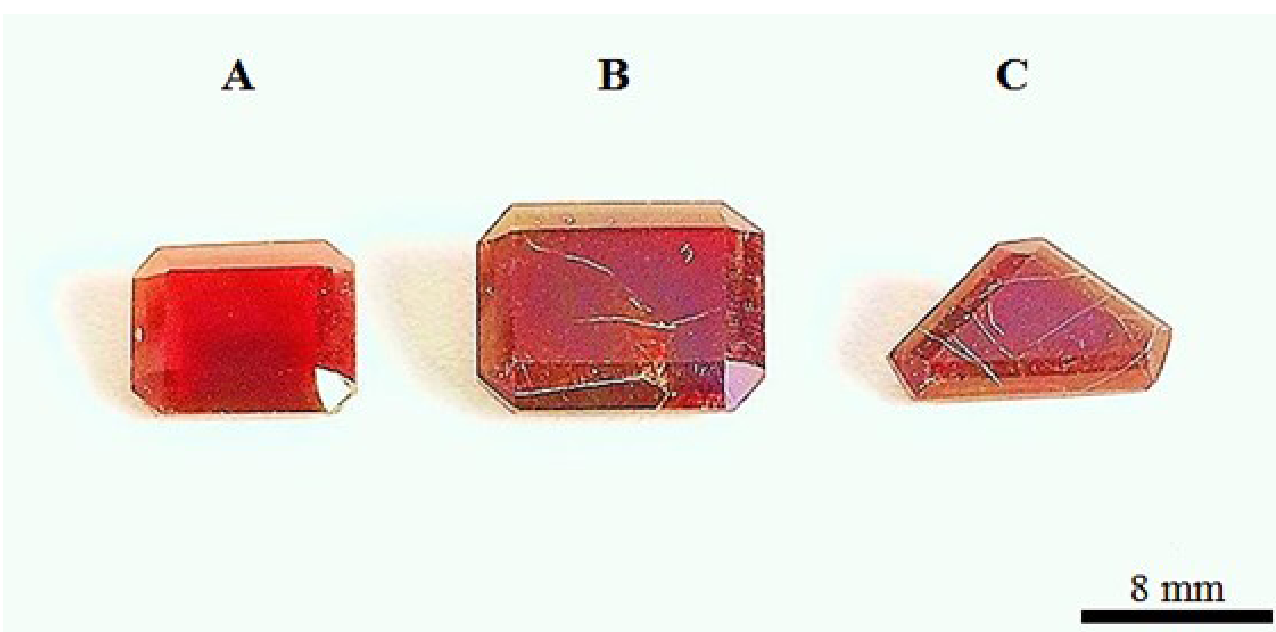

Figure 2 Analyzed staurolites from the Casa Nova city, Bahia, Brazil: A. Staurolite (Red 3) with the following dimensions: 8.62 x 7.53 x 3.48 mm; B. Staurolite (Brown 4) with 11.12 x 8.06 x 5.25 mm. C. Staurolite (Brown 4) with 10.31 x 6.53 x 4.26 mm.

crystal) with known refractive indices and birefringence was used to test the calibration of the refractometer.

3.2 Polariscope

We employed a GIA polariscope with a coupled light source. This instrument allows to identify whether the analyzed material is anisotropic or isotropic. The instrument consists of two polarizing plates, called polarizer sets (Hurlbut Jr & Switzer 1979). The method consists of leaving the polarization plates perpendicular to each other and rotating the mineral, placed between the plates.

3.3 Hydrostatic Scale

We obtained the relative density of the gemstones using a hydrostatic balance. Relative density is a property independent of the location and size of the analyzed samples. It is defined as weight per volume, represented in g/cm^3 or kg/m^3 (Schumann 2020). Two scales were used, one hydrostatic (Marte AD5002) and the other analytical (AND HR200) to ensure maximum precision in the density of the samples (Schumann 2020).

3.4 Dichroscope

We determined the pleochroism of the gemstones using a dichroscope. Pleochroism is caused by the distinct absorption of light in birefringent crystals, which can be strong, moderate, or weak. This phenomenon does not occur in isotropic, amorphous, and opaque gems, not in most translucent ones (Schumann 2020). To measure it, we employed a portable dichroscope from GIA (Gemological Institute of America).

3.5 Ultraviolet Light Lamp

We used a ultravioletlamp from GIA (Gemological Institute of America) to test the fluorescence of the gemstones. Fluorescence is a very important method for the identification of gemstones since it is caused by the presence of unusual activating chemical elements in the mineral's crystalline structure (Schumann 2020).

3.6 Spectroscope

We employed a portable spectroscope from GIA (Gemological Institute of America) without a coupled light source to determine the absorption bands of the gemstones. In a very similar way to the dichroscope, the material is analyzed through the spectroscope, requiring moderate luminosity (artificial or natural) (Schumann 2020).

3.7 Gemological Microscope

We employed a Meiji EMZ 75339 gemological binocular microscope with a coupled light source was used with defined magnification objectives (0.7X, 1X, 1.5X, 2X, 2.5X, 3X, 3 .5X, 4X 4.5X), 16X magnification eyepieces. This equipment allows immediate reading of the various types of color zoning, solid inclusions, fractures in the crystal structure (healed fractures), spots and crystal changes (fingerprints) and acicular inclusions (silk inclusions) (Franco 1961) (Oliveira 1967) (Anderson 1984) (Hughes 2017). Samples were analyzed using a light background.

3.8 Scanning Electron Microscope (SEM)

The equipment we used and is available at DEGEO/UFC (HITACHI TM-3000) is coupled to an energy dispersive spectrometer (EDS, SWIFT ED-3000 – Oxford Instruments). This instrument routinely used for the microstructural analysis of solid materials and their chemical compositions, making it possible to gauge which elements are present and their quantities (Nagatani et al. 1987).

4 Results and Discussions

Through analyses by commercial color table, it was determined that the staurolites from the city of Casa Nova in Bahia (Brazil) have red and brownish red colors and only one gem (Red 3) has a color considered excellent by the trade. The other two samples do not have the ideal saturation and tonality. To be properly valued, the staurolites may have their respective colors with more balanced saturation and tonality. The red color had a highly valued in staurolites, as long as they have the right saturation and hue (Arem 2024). Gemologically the data acquired was compared with the base of worldwide data from the International Gem Society (IGS) (Arem 2024) and in several works of great recognition and worldwide credibility, works from 1971 to 2020 (Franco & Campos 1971) (Hurlbut & Switzer 1979) (Nassau 1980) (Webster 1981) (Anderson 1984) (Schumann 2006) (IBGM & Gama 2009) (Bonewitz 2013) (Schumann 2020).

According to our readings using the refractometer and with the use of polariscope, all the three gems are anisotropic. The refractive index of the analyzed staurolites, measured with the refractometer, has values within the normal range; however, the two darkest gemstones (Brown 4) have refraction slightly above (0.004) of normality, it is known that the increase in the amount of FeO has a direct influence on the refractive index of staurolites. The most gemological sample Red 3 has the refractive index of 1.746(nz) -1.735(nx). The two darkest crystals Brown 4 have a have indices of 1.765(nz)-1.750(nx) and 1.765(nz)-1.749(nx). The refraction of staurolites ranges from 1.739 to 1.761 (Arem 2024) and most commonly 1.736 to 1.750 (IBGM & Gama 2009) (Bonewitz 2013) (Schumann 2020). A slight correlation was noted between color and refractive indices in these staurolites, the deeper and closer to brown, the higher the refractive index, and the closer the color to red, the lower the measured refraction. This observation can be better understood and studied by obtaining more samples. The tree staurolites analyzed are biaxial (+), which is the normality for staurolites (Franco & Campos 1971) (Hurlbut & Switzer 1979) (Webster 1981) (Schumann 2006) (Arem 2024).

The birefringence of Casa Nova staurolites ranges between 0.011 (Red 3) and 0.016 (Brown 4). There is a tenuous correlation between the double refraction of the samples and the color and refractive index; the samples with the highest double refraction are the same ones that have the highest refractions and color closest to brown. It is known that inclusions and defects in the crystal lattice of minerals influence the speed of light propagation within the mineral. Such as the chemical composition itself, in which the elements allied to their oxidation state, quantity and position in the crystalline reticulum interfere with the routing of light through the mineral; in the case of staurolites and other minerals, the FeO has direct interference (Flint 1965) (Wahlstrom 1969) (Anderson 1984) (Fujimori & Ferreira 1987) (Roberts et al. 1990) (Mazdab 2001) (Machado & Nardy 2016) (Schumann 2020) (Arem 2024). The birefringence of staurolites oscillates between 0.009-0.015 (Anderson 1984) (IBGM & Gama 2009) (Schumann 2020) (Arem 2024).

After analyzing the three samples using a polariscope, none anomalies were found. The gemstones showed the expected behavior of anisotropic minerals, becoming totally extinct every 90 degrees and allowing the passage of light in these intervals. Despite the low visibility of the two Brown 4 samples, caused by the low diaphaneity and dark color, it was possible to visualize the anisotropy (Schumann 2020) (Arem 2024).

The relative density, measured using a hydrostatic balance, presented results within expectations, but with some reservations. The gem Red 3 has density of 3.69 g/cm^3. The staurolites Brown 4 have densities of 3.85 and 3.84 g/cm^3, respectively. The density of staurolites ranges between 3.65 and 3.83 g/cm^3 (Arem, 2024), therefore, the values obtained for the gems are within the world standard. Values slightly above the average of Brown 4 specimens can be considered within the normal range; as the hydrostatic balance is a highly sensitive instrument, any slight change in temperature, air current, vibration, could cause a slight oscillation in the balance values (Anderson 1984) (Klein & Dutrow 2012) (Schumann 2020).

Dichroism, or pleochroism, which is analyzed with the dichroscope, showed the absence of this characteristic in all samples. The absence of pleochroism is an uncommon feature in staurolites (Hurlbut & Switzer 1979) (Nassau 1980) (Webster 1981) (Anderson 1984) (Schumann 2006) (IBGM & Gama 2009) (Bonewitz 2013) (Schumann 2020) (Arem 2024). This phenomenon, dichroism, results from the distinct absorption of light in anisotropic crystals. This occurs due to the different speeds of propagation and absorption of light in the mineral, a consequence of the crystalline system. Stauriolites crystallize in the monoclinic system, due to the orientation and crystallographic parameters, the light refracting inside the mineral is divided into 3 rays (nz, ny and nx) that vibrate perpendicular to each other. Minerals from the orthorhombic, monoclinic and triclinic systems share this characteristic and could exhibit up to 3 colors of pleochroism, because of the 3 distinct velocities of propagation and absorption of light (Flint 1965) (Wahlstrom 1969) (Fujimori & Ferreira 1987) (Machado & Nardy 2016). Then, the analyzed samples not exhibiting pleochroism is rare and unusual.

The use of an ultraviolet light lamp allowed the observation of fluorescence, which could not be seen in any of the analyzed staurolites, as already expected for these minerals (Franco & Campos 1971) (Nassau 1980) (Webster 1981) (IBGM & Gama 2009) (Schumann 2020) (Arem 2024). This data shows that the samples do not have fluorescence or phosphorescence activating elements, such as chromium and rare earth elements. The element releases the accumulated energy in the form of light when energized and returning to its normal and stable valence (Anderson 1984).

Absorption spectra is a qualitative step of certain chemical elements, in which transition metals (Fe^{2+}, Fe^{3+}, Mn^{2+}, Mn^{3+}, Cu^{3+}, Mg^{2+} etc.) have a transmission at certain wavelengths, such as 490 nm, being related to Mn^{2+} and 700 nm to Cu^{2+} in some minerals. The absorption spectrum of the gems analyzed by the spectroscope matches the pattern of the staurolites. The analyzed staurolites samples have spectra in the order of 450 nm. Staurolite, on a world scale, has as standard ditches: 580 and 450 nm (Anderson 1984) (Bonewitz 2013) (Arem 2024).

Under the gemological microscope, the gems analyzed showed fractures, irregularly distributed solid inclusions, single-phase fluid inclusions without orientation. Due to the low visibility (color and mainly diaphaneity)

Table 1 Gemological characteristics and chemical contents obtained by the EDS method of the staurolites from Casa Nova – Bahia.

Color	Red		Red		Red	
Sample	(Red 3)		(Brown 4)		(Brown 4)	
Diaphaneity	Translucent		Semi translucent		Semi translucent	
Refractive index; birefringence	1.746 – 1.735; 0.011		1.765 – 1.749; 0.016		1.765 – 1.750 ; 0.015	
Character and optical signal	Biaxial (+)		Biaxial (+)		Biaxial (+)	
Pleochroism	Absent		Absent		Absent	
Absorption Spectrum	450 nm		450 nm		450 nm	
Fluorescence	Absent		Absent		Absent	
Density	3.69 g/cm³		3.85 g/cm3		3.84 g/cm³	
Inclusions and internal aspects	Fractures; Single-phase fluid inclusions without orientation		Fractures; irregularly distributed solid inclusions; Single-phase fluid inclusions without orientation		Fractures; irregularly distributed solid inclusions; Single-phase fluid inclusions without orientation	
Chemical Contents (%)	ELEM	WT%	ELEM	WT%	ELEM	WT%
	Al_2O_3	50.26	Al_2O_3	44.72	Al_2O_3	45.54
	Cr_2O_3	0.59	CaO	0.57	CaO	0.59
	FeO	16.00	FeO	20.29	FeO	20.76
	MgO	2.25	MgO	5.44	MgO	5.05
	SiO_2	30.89	SiO_2	28.90	SiO_2	27.88
Chemical formula	$Fe_2Al_9Si_4O_{23}(OH)$		$Fe_2Al_9Si_4O_{23}(OH)$		$Fe_2Al_9Si_4O_{23}(OH)$	

of the samples, especially the Brown 4 samples, it was not possible to obtain more information and good figures about the inclusions and internal aspects of the staurolites from Casa Nova (Bahia).

The diaphaneity analysis of the specimens took place through the visualization of an object, pen tip, through the staurolites. The image has a well-defined outline and sharpness in transparent samples. In semi-transparent samples the sharpness is not as visible, while in translucent samples the outline is defined and sharpness is almost absent. In semi-translucent staurolites analyzed the outline is poorly defined and sharpness is absent.

Therefore, this data was compiled in a table (Table 1), together with the geochemical data of the staurolites, as part of the characterization of the minerals.

The general formula for the staurolites is $Fe_2Al_9Si_4O_{23}(OH)$. The formula can also be considered as alternating layers of kyanite and oxide, and so it can be recast as: $4Al_2O[SiO_4]AlFe_2O_4H$. This mineral is a nesosilicate; common impurities found in staurolite are: Ti, Cr, Mn, Co, Zn, Li, and H_2O (Skerl & Bannister 1934) (Anderson 1984) (Roberts et al. 1990) (Mazdab 2001) (Deer et al. 2010) (Schumann 2020) (Arem 2024).

The presence of these chemical elements and their amounts (Table 1) directly influence staurolite characteristics, such as refractive index, birefringence, relative density, and inclusions. In this paper, three samples were used, but a greater number of chemical analyses in more samples would make the correlation more visible. The red staurolite (Red 3) has very different values when compared with the other two samples (Brown 4). Similar to tourmalines from the Quixeramobim region (Oliveira et al, 2020), the analyzed gems have amounts of CaO, except the crystal Red 3. As expected, the gems Brown 4 have a low amount of CaO (0.57 and 0.59%); the red staurolite has 0.59% of Cr_2O_3, rather than CaO in its chemical composition. Intrinsically, Cr is a common impurity in staurolite, but Ca is not. Commonly, Cr_2O_3 occurs in amounts up to about 1% (Mazdab 2001) (Deer et al. 2010).

Both brown staurolites (Brown 4) have the same color, refractive index, birefringence, relative density, and similar chemical content. The amount of 44-50% Al_2O_3 in all these specimens is lower than would normally be expected in staurolites; the normality for this mineral is around 52–54% (Skerl & Bannister 1934) (Roberts et al. 1990) (Mazdab 2001) (Deer et al. 2010). However, the three samples have a large content of FeO, between 16% (Red 3) and 20.2–20.7% (Brown 4); normally the FeO is present in staurolites in more modest quantities, among others 9–13% (Skerl & Bannister 1934) (Roberts et al.

1990) (Mazdab 2001) (Deer et al. 2010). In the case of the samples in this paper, the Fe is in greater quantity because it is replacing Al within the crystalline reticulum. Due to the high geochemical compatibility (density, mass, atomic radius, and oxidation state) between Fe and Al, this substitution is very common in minerals. Furthermore, there is a correlation between color, refractive index, birefringence, relative density, and the amounts of FeO in staurolites from this paper: the greater the amount of this element, the greater the refractive index, birefringence, relative density and the dark intensity of the color. It is due to the fact that the Fe is the densest element among those present in staurolites from Casa Nova (Bahia), and it influences the color and refraction index of the staurolites (Dana & Hurlbut Jr 1960) (Mazdab 2001) (Deer et al. 2010) (Klein & Dutrow 2012) (Arem 2024).

The FeO is not the only chemical element replacing the Al in the samples, but the Mg is also replacing it. Normally, the MgO present in staurolites oscillates between 0.5 and 3% (Roberts et al. 1990) (Mazdab 2001) (Deer et al. 2010); in the samples from Casa Nova the values obtained range from 2.25 (Red 3) to 5.44 (Brown 4). Thus, the Fe and Mg contributed significantly to the decrease of Al in the samples of Casa Nova; these two metals entered the reticulum, replacing Al. Subsequently, studies focused on the formation conditions of these minerals could be conducted to find out under what conditions this geochemistry substitution was possible.

The amount of SiO_2 in the 3 staurolites oscillates between 27.88% (Brown 4) and 30.89% (Red 3), in addition to not showing any correlation neither with the gemological properties nor with others chemical elements. The amount of SiO_2 present in the studied samples is within the normal range; thus, normally and worldwide, SiO_2 oscillates between 27 and 29% (Skerl & Bannister 1934) (Roberts et al. 1990) (Mazdab 2001) (Deer et al 2010).

All these cited data were organized in a table (Table 1) as the final product of the characterization of staurolites from Casa Nova (Bahia).

5 Conclusions

Through the data obtained in the gemological characterization and mineral chemistry, it was possible to establish that the staurolites from the municipality of Casa Nova (Bahia) have the potential to be used as gemstones; the Red 3 gem has an intense color (and rare for staurolites) and gemological quality; the other Brown 4 specimens have a very common color for staurolites, however their diaphaneity could be better. However, some peculiarities were also observed some peculiarities in addition to the color already mentioned in one of the samples: the complete absence of pleochroism in staurolites and the high density in two specimens. Gemologically, the gems of Casa Nova (Bahia) have standard characteristics and are within the average of this mineral, although the refraction and birefringence are almost at the average limit. The staurolites in the region are anisotropic and have three refractive index, as expected. Both gems do not have fluorescence. Moreover, the absorption spectrum is considered the standard. Microscopically, the minerals in the region have fractures, irregularly distributed solid inclusions, and single-phase fluid inclusions without orientation. The high density of two specimens (Brown 4) could have a direct correlation with the geochemistry of staurolites. In the minerals in this paper, Al is being replaced in considerable quantities by Fe and Mg; since the Al content is below normal and the Fe and Mg content are considerably above average. In addition, the Red 3 gem has Cr in its structures, and the two brown samples have Ca; the latter impurity is not something common in staurolites. There seems to be a direct correlation between the amount of Fe and the color, refractive index, birefringence, and relative density of staurolites from Casa Nova. More detailed studies can be done with more samples about the geochemistry of minerals in the region; in addition, studies focused on the formation conditions of these minerals could be conducted to find out under what conditions this geochemistry substitution was possible.

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Isaac Gomes de Oliveira: writing – original draft; funding acquisition; investigation; methodology; project administration; visualization; validation. **Breno Ravielly dos Santos:** software; conceptualization; **Larissa De Sousa Silva:** software; conceptualization; **Isabelle Pinto Bezerra:** methodology; writing - review and editing; corresponding author. **Antonio Leal Neto:** supervision; validation; **Lucilene dos Santos:** supervision; validation. **Tereza Falcão de Oliveira Neri:** supervision; validation;

Conflict of interest

The authors declare no potential conflict of interest.

Data availability statement

All data included in this study are publicly available in the literature.

Funding information

This work was supported by a doctoral scholarship from FUNCAP awarded to Isaac Gomes de Oliveira.

Editor-in-chief

Dr. Claudine Dereczynski

Associate Editor

Dr. Gustavo Luiz Campos Pires

How to cite:

Oliveira, I. G., Bezerra, I. P., Santos, L., Santos, B. R., Silva, L. S., Leal Neto, A. & Neri, T. F. O. 2024, 'Gemology and Geochemistry of Staurolites from the Casa Nova Region, Brazil', *Anuário do Instituto de Geociências,* 47:62755. https://doi.org/10.11137/1982-3908_2024_47_62755