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Mineralogical Characteristics and Their Usability as Gemstones of Jaspers in Altered Metavolcanics Belonging to the Topçam Formation, Tokat, Turkiye

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Abstract: The jaspers located in the Topçam Mountain, Tepeyurt region (Tokat, Turkey), were formed at green-colored metavolcanic levels within Permian–Triassic schists. The sizes of the jaspers generally vary from a few cm to 1.5 m, and their colors vary from grayish–reddish–brownish/blackish tones depending on the increase in the amount of Fe and Mn elements they contain. According to thin section and X-ray Diffraction (XRD) analysis examinations, it was determined that the composition of jaspers includes quartz, hematite, calcite, and pyrite. As stated by the Wavelength Dispersive X-ray Fluorescence (WDXRF) analysis results, it was observed that the amount of SiO_2 in jaspers was 82.5%, and the amount of Fe_2O_3 was 15.5%. According to Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) analysis results, Fe and Mn impurities, which are thought to cause the color of jaspers, as well as the amount of Fe (6975.5 ppm–46,893.9 ppm–96,431.1 ppm) and the amount of Mn (935.9–3219.7–6040.4 ppm), caused a darkening in color tones (grayish–reddish–brownish/blackish). Cabochon cutting applications were made of jaspers taken from the study area. As a result of these applications, it has been determined that jaspers can be used as gemstones due to their properties, such as their workability, polish retention, and color and light reflection.

Keywords: jasper; mineralogy; petrography; gemology; Tokat

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1. Introduction

The Tokat region, where the study area is located, is very rich in siliceous gemstones. Petrified woods [1], chrome chalcedonies [2], blue chalcedonies [3], agates [4], and jaspers [5], are some of them. Unlike chalcedony, which generally consists of fibrous/needle-like tissue, jasper, known for its unique reddish color consisting mostly of microcrystalline tissue, is among the precious stones belonging to the quartz group [6,7]. The name jasper comes from the Greek word "iaspis", meaning spotted or spotted stone [8]. Jaspers are hard, opaque siliceous rocks with conchoidal fractures, often having banding or a mottled structure, generally consisting of Al and Ca impurities [9]. They are usually red, green, yellow, or brown in color. The colors are caused by included minerals. Specifically, hematite gives red and pink tones; iron oxides give yellowish or brown tones; and chlorite, actinolite, and epidote give greenish tones [10,11]. The chemical composition of jasper is SiO_2, and it may contain traces of Al, Ca, Fe, K, Mg, and Mn impurities. Its hardness is between 6.5–7.0 [12]. Its specific gravity is between 2.58–2.91 g/cm^3, and it has no pleochroism, fluorescence, and cleavage quality [13]. Jaspers have a variety of colors and textures, with properties such as density, polish, and decorative effect making them an important raw material for the jewelry industry [10].

Jaspers are generally formed due to hydrothermal activity, and they can occur in volcanic and sedimentary rocks, as well as hydrothermal veins. The formations of jaspers can be grouped under three main headings [14]. These are as follows:

(1) Metasomatism, occurring during volcanic exhalations and the diagenesis of basement volcanic and volcanic sedimentary material in proximal metamorphic facies,
(2) As a result of hydrothermal SiO_2 autometasomatism of volcanogenic rocks, and
(3) Contact of hornfels-type metamorphic rocks and tufogenic units with postvolcanic metasomatism.

Additionally, jaspers can be formed as a result of metamorphic processes in low-temperature metamorphic facies. Jaspers may also form as products of the metamorphism of greenschist facies or metasomatic replacement and contact metamorphism [15].

The jaspers formed as volcanogenic–sedimentary metamorphic and hydrothermal–metasomatic products of the dominant quartz composition are true jaspers. The jaspers formed as a result of the postvolcanic SiO_2 formation of the dominant chalcedony composition are jasperoids. In addition, quartzites and hornfels formed by higher degrees of recrystallization are jasper-like structures [16].

Jasper is used extensively in the field of gemology, generally in ornaments, jewelry, and decoration products. Jasper appears in all known history, and was used for tools and ornaments. Jewelry, knives, and arrowheads that were used by Paleolithic people, who are considered the ancestors of Native Americans, and are approximately 12,000 years old, were found in Pennsylvania, USA [17]. Primitive stone axes made of jasper, dating back 2.5 million years, were also found in Ethiopia [18].

Jasper has been used as an important stone in almost all religious and cultural history in the world. For example, for Christians, youth represents the power of faith, and the cornerstone of the church built for Christ is jasper [17]. For Hebrews, it is the twelfth stone in the armor of the high priest, and the seal stone of Chinese emperors from past to present. Jaspers, which are stones of protection for Native American shamans, also have an important place in many other beliefs [8]. Furthermore, in a museum in St. Petersburg in Russia, there is a jasper vase from the 1800s, carved in one piece, weighing 19.2 tons [17].

The aim of this study is to examine in detail the mineralogical properties of jaspers found in altered metavolcanics belonging to the Topçam Formation in Tokat province, to determine the usability of these stones as precious stones, and to evaluate their economic potential.

Geology

The oldest unit in the study area consists of metamorphic rocks consisting of Permian–Triassic schists and marbles (Figure 1). These units are overlain by tectonic contact with the Middle-Upper Triassic diabase and Upper Cretaceous ophiolites. All of these units are unconformably covered by Pliocene-aged continental clastics and Quaternary-aged alluviums. Furthermore, jaspers accompany manganese zones within schists.

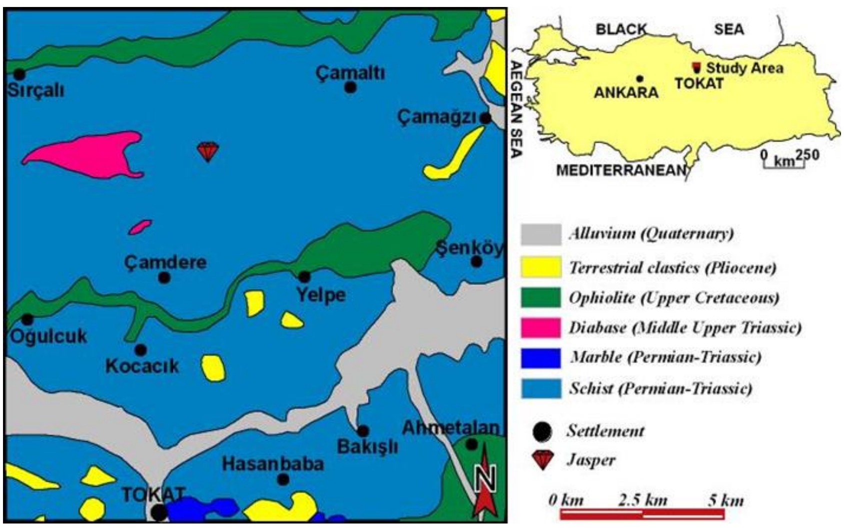


Figure 1. Geological map of the study area and its immediate surroundings [19,20].

2. Materials and Methods

In order to determine the mineralogical–petrographical, geochemical, and gemological properties of the jaspers examined, samples were taken from the manganese ore field located in Topçam Mountain Tepeyurt Location in Tokat Province. Thin sections were prepared in the Mersin University Geological Engineering Department's Thin Section Laboratory, and examined under a bottom-illuminated polarizing microscope in Mineralogy–Petrography Laboratory in Department of Geological Engineering in Kırşehir Ahi Evran University. X-ray Diffraction (XRD) analyses were performed on unoriented powder samples in the range of 2 theta, 5–90 degrees, on the Rigaku RadB-DMAX II, which was computer-controlled and performed on a model X-ray Diffractometer at the Mersin University Advanced Technology Education, Research and Application Center (MEITAM).

Wavelength Dispersive X-ray Fluorescence (WDXRF) analyses were performed on pressed powder samples (pellets) using the Rigaku ZSX Primus II-brand wavelength-dispersive at the Mersin University Advanced Technology Education, Research and Application Center (MEITAM). Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) analyses were performed on samples put into solution on an Agilent brand, 7800 Quadropole model Inductively Coupled Plasma-Mass Spectrometer device at the Atatürk University, Eastern Anatolia High Technology Application and Research Center (DAYTAM) in Erzurum.

Hardness, density, and brightness analyses were performed on jaspers taken from the study area at the Kırşehir Ahi Evran University Rock Mechanics Laboratory. The hardness test was conducted using a Leeb hardness tester, while the brightness test was performed using a gloss meter. In addition, Cabochon cutting techniques were used on jasper samples taken from the study area by using diamond-coated saws, sintered diamond grinding discs, and polishing machines to determine their usability as a gemstone.

3. Results

3.1. Field Investigation

The study area is located at the Tepeyurt Locality of Topçam Mountain, located to the north of the Tokat city center. Furthermore, jaspers are located within Permian–Triassic metamorphic levels (Figure 2a). As a result of hydrothermal activities occurring in the region, metavolcanic rocks have undergone alteration, and there are jaspers accompanying manganese ores in these alteration zones (Figure 2b). Jaspers are observed in manganese and metavolcanic rock contacts (Figure 2c). Although the sizes of jaspers vary, they generally range from a few cm to 1.5 m. Their color is usually dark red or brownish red (Figure 2d). They contain very thin gray-black veins and plenty of quartz veins due to alteration, and they also have many broken and cracked structures.

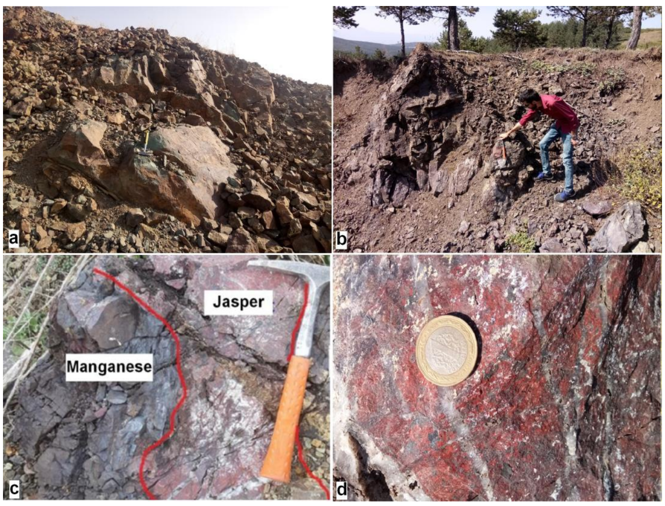


Figure 2. Metavolcanics containing jaspers (**a**), manganese, and jaspers in metavolcanics (**b**–**d**).

3.2. Mineralogical–Petrographic Investigation

Polarizing Microscope (Thin Section) Investigation

In thin section examinations made under a polarizing microscope, it was determined that the host rock had undergone intense alteration and had a microcrystalline volcanic rock texture as its residual texture. Feldspars found as phenocrysts in the metavolcanic rocks are completely sericitized (Figure 3).

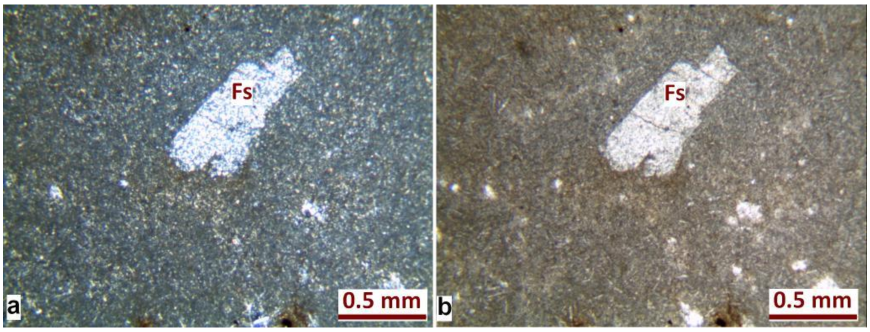


Figure 3. Sericitized feldspar (Fs) mineral observed in altered metavolcanic rock (**a**): +N (cross-polarized light); (**b**): //N (plain-polarized light).

Jasper consists of fine-grained quartz (Qtz) and iron oxide (FeO) minerals (hematite) as its opaque minerals (Figure 4a,b). In some samples, secondary calcite (Cal) filling in the form of veins was observed (Figure 4c,d).

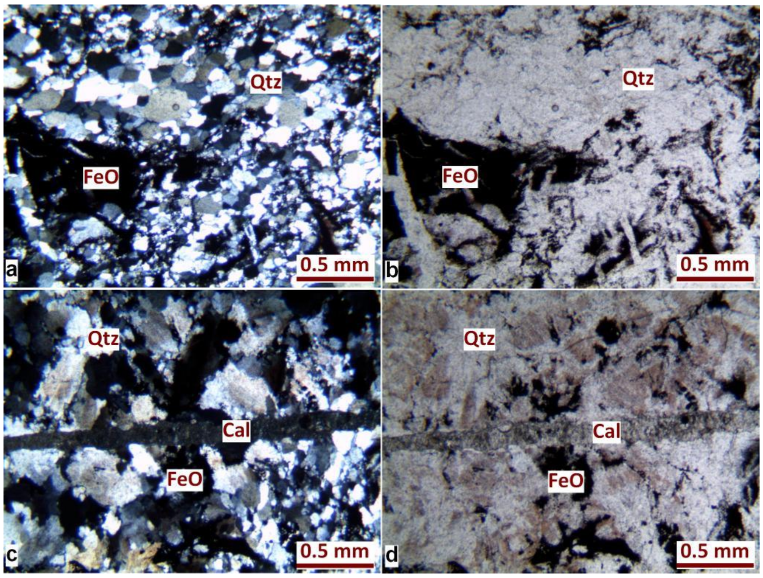


Figure 4. Quartz (Qtz), iron oxide (FeO) mineral, and secondary calcite (Cal) vein in jasper (**a**,**c**): +N (cross-polarized light); (**b**,**d**): //N (plain-polarized light).

3.3. XRD (X-Ray Diffraction) Investigation

In the jasper, there are white levels in the form of veins reaching a thickness of several cm, and black and red levels are intertwined (Figure 5). XRD analysis was performed on the samples obtained as a result of the enrichment process from these regions with different colors.

As a result of XRD analysis, the presence of quartz, hematite, and calcite in the white parts of the jasper sample (Figure 6); the presence of quartz, hematite, calcite, and pyrite in the red parts (Figure 7); and the presence of quartz, hematite, calcite, and pyrite in the black parts was determined. (Figure 8).

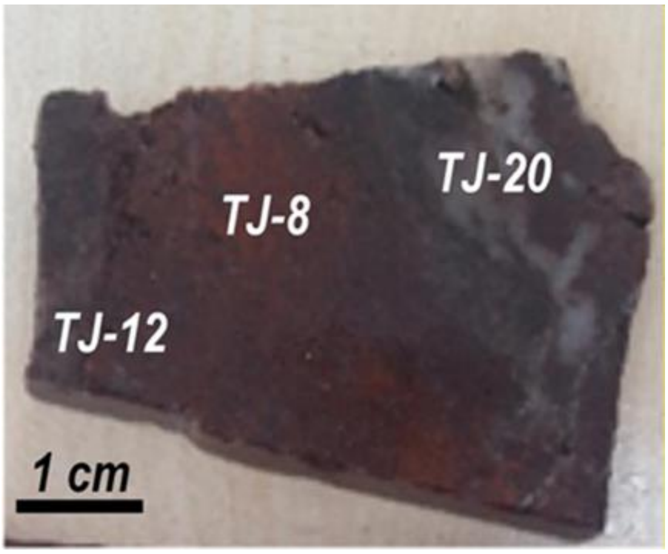


Figure 5. Different colored levels within the jasper (TJ-8: red, TJ-12: black, TJ-20: white).

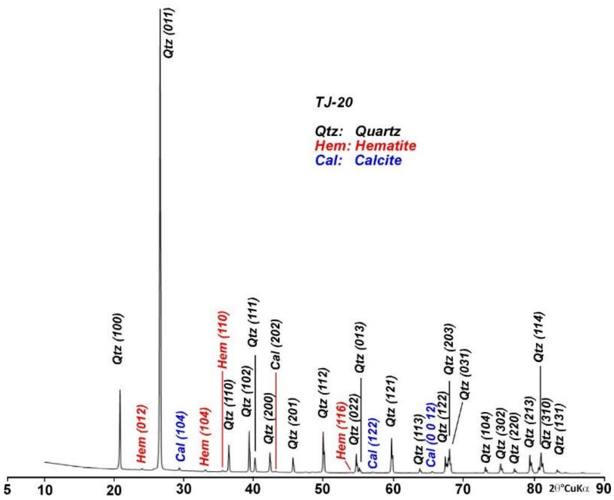


Figure 6. XRD analysis of the white-colored parts of the jasper sample.

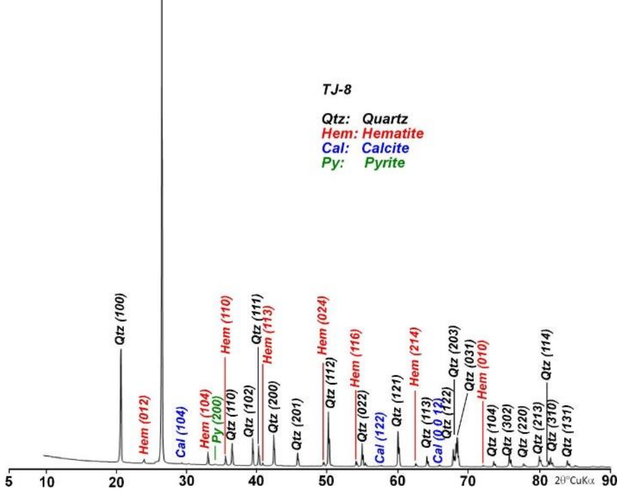


Figure 7. XRD analysis of the red-colored parts of the jasper sample.

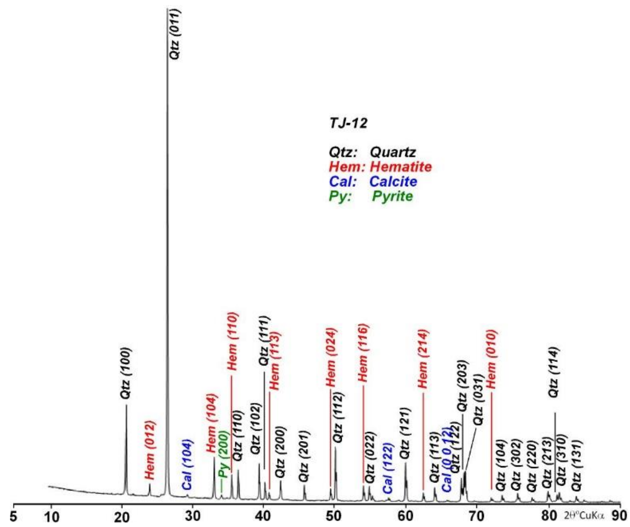


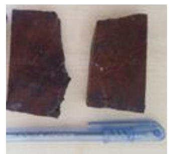
Figure 8. XRD analysis of the black-colored parts of the jasper sample.

3.4. Geochemistry Investigation

WDXRF (Wavelength Dispersive X-Ray Fluorescence) Investigation

The host rock samples (TA-12) taken from the study area were analyzed using Wavelength Dispersive X-ray Fluorescence (WDXRF) to determine their chemical composition. The results indicated that the samples contained 48.00% SiO_2, 13.3% CaO, 12.7% Fe_2O_3, 11.5% Al_2O_3, and 7.83% MgO (Table 1).

Table 1. WDXRF analysis results of host rock and jasper samples in the study area.

(%Mass)	 **TA-12 (Host Rock)**	 **TK-25 (Jasper)**
SiO_2	48.000	82.500
CaO	13.300	1.070
Fe_2O_3	12.700	15.500
Al_2O_3	11.500	0.283
MgO	7.830	0.119
Na_2O	2.580	0.054
TiO_2	2.580	0.000
K_2O	0.761	0.026
P_2O_5	0.307	0.126
MnO	0.196	0.256
SO_3	0.055	0.066
SrO	0.036	0.000
ZnO	0.021	0.021
NiO	0.014	0.000
CuO	0.010	0.000
Cl	0.000	0.012

In addition, a representative sample of jaspers, designated as TK-25, was subjected to the same WDXRF analysis. The findings revealed that the jasper sample contained 82.5% SiO_2, 15.5% Fe_2O_3, 1.07% CaO, 0.256% MnO, 0.283% Al_2O_3, and 0.119% MgO (Table 1).

According to the results of the WDXRF analysis performed on manganese samples taken from the study area, it was determined that the amount of Mn was 48.45%, the amount of SiO_2 was 13.75%, and the amount of Fe was 1.16% (Table 2).

Table 2. WDXRF analysis results from manganese samples taken from the study area.

(%Mass)	TM-1 (Manganese)
SiO_2	13.75
Mn	48.45
Fe(total)	1.16

The WDXRF analysis of the manganese samples associated with jaspers in the study area (Figure 2c) revealed that the Mn content was 48.45%, with SiO_2 at 13.75%, and iron (Fe) at 1.16% (Table 2).

3.5. ICP-MS (Inductively Coupled Plasma-Mass Spectrometry) Investigation

The Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) analysis of the host rock sample (TA-12) from the study area revealed the following concentrations: iron (Fe) at 79,165.77 ppm, cesium (Cs) at 77,041.35 ppm, aluminum (Al) at 61,258.23 ppm, potassium (K) at 21,213.70 ppm, magnesium (Mg) at 12,385.09 ppm, calcium (Ca) at 11,254.90 ppm, titanium (Ti) at 7902.02 ppm, and manganese (Mn) at 2566.54 ppm (Table 3).

Table 3. ICP-MS analysis results from host rock and jasper samples taken from the study area.

Conc. [ppm]	 TA-12 (Host Rock)	 TK-25 (Jasper)
	ppm	ppm
Li	20.240	0.000
Be	0.620	0.010
B	10.780	0.000
Na	5335.020	212.330
Mg	12,385.090	3735.460
Al	61,258.530	4185.100
P	1946.040	117.610
K	21,213.770	1355.730
Ca	11,254.900	6497.600
Sc	26.620	1.220
Ti	7902.020	91.750
V	263.390	27.950
Cr	206.280	204.640
Mn	2566.540	8246.810
Fe	79,165.770	41,905.180
Co	42.080	15.520
Ni	97.960	136.610
Cu	51.260	72.200
Zn	106.310	35.690
Ga	22.230	1.950
Se	0.710	0.000
Rb	6565.420	504.870
Sr	287.220	43.910
Y	20.490	0.850
Nb	3594.220	393.970
Sb	0.590	0.220
Cs	77,041.350	176,483.000
Ba	412.070	10.330
La	11.640	0.590
Ce	27.560	0.980
Pr	3.860	0.080
Nd	18.230	0.500
Sm	4.530	0.040
Eu	1.730	0.000

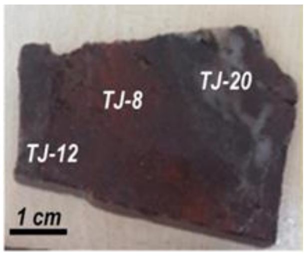
Table 3. *Cont.*

Conc. [ppm]	 TA-12 (Host Rock)	 TK-25 (Jasper)
	ppm	**ppm**
Gd	5.190	0.080
Tb	0.710	0.000
Dy	4.280	0.070
Ho	0.750	0.000
Er	2.010	0.010
Tm	0.190	0.000
Yb	1.430	0.000
Lu	0.120	0.000
Pb	2.430	0.240
U	0.240	0.000

The results of ICP-MS analysis of the jasper sample (TK-25) showed the following content: cesium (Cs) at 176,484.00 ppm, iron (Fe) at 41,905.18 ppm, manganese (Mn) at 8246.81 ppm, 6497 calcium (Ca) at 0.60 ppm, and aluminum (Al) at 4185.10 ppm (Table 3).

The ICP-MS analysis of the white parts of the jasper samples (TJ-20) from the study area showed the following elemental concentrations: cesium (Cs) at 78,614.49 ppm, iron (Fe) at 6975.49 ppm, silicon (Si) at 18,604.98 ppm, and manganese (Mn) at 935.87 ppm (Table 4).

Table 4. ICP-MS analysis results from the white, black, and red parts of jasper samples taken from the study area.



	TJ-20: White	**TJ-12 Black**	**TJ-8: Red**
	ppm	**ppm**	**ppm**
Na	592.566	796.082	264.680
Mg	104.641	1153.210	363.541
Al	400.235	3396.955	1604.638
Si	186,041.958	186,928.229	241,341.791
P	29.591	1322.346	262.354
K	315.775	395.322	0.000
Ca	1293.392	1302.551	463.350
Ti	9.821	78.183	42.947
V	4.376	69.949	39.148
Mn	935.878	6040.407	3219.715
Fe	6975.496	96,431.074	46,893.906
Co	1.475	17.000	4.810
Ni	14.439	48.921	74.757
Cu	2813.686	2894.646	6129.106
Zn	1652.259	1662.692	3512.637
Se	1.926	0.000	0.000
Pb	196.377	171.763	387.341
Cs	78,614.384	13,945.647	36,836.487
Rb	0.104	0.210	0.098

In the black parts of the jasper samples (TJ-12), the ICP-MS results indicated cesium (Cs) at 13,945.64 ppm, iron (Fe) at 96,431.07 ppm, silicon (Si) at 186,928.22 ppm, and manganese (Mn) at 6040.40 ppm (Table 4).

For the red parts of the jasper samples (TJ-8), the analysis revealed cesium (Cs) at 36,836.48 ppm, iron (Fe) at 46,893.90 ppm, silicon (Si) at 241,341.79 ppm, and manganese (Mn) at 3219.71 ppm (Table 4).

These results reveal that different color zones of jasper have different geochemical properties.

Since jasper is the host rock of manganese ore in the study area, and considering its chemical composition, it is seen that the manganese (Mn) values, which are expected to be high, are low. In addition, its iron (Fe) and cesium (Cs) values are relatively high.

3.6. Gemstone Studies

The jaspers in the study area are observed in brownish and reddish colors, with a waxy–oily luster, and in an opaque state. They also contain structures in the form of grayish–blackish spots and white veins (Figure 9). The Leeb hardness test [21,22] conducted on the jasper sample collected from the study area revealed that the white part has a hardness of 920 HL, while the red part has a hardness of 830 HL. As a result of the density test, the density of the jasper sample was measured as 2.78 g/cm^3. In the brightness test performed on the jasper, the gloss value was measured at 0.2 before polishing, and it increased to 95 after the polishing process. The hardness, durability, brightness, and different color varieties of these jaspers, and their unique patterns, enhance their visual appeal. Due to these features, it has been deemed appropriate to apply cabochon cutting. Cabochon cutting applications were made in oval, circle, drop, square, triangle, etc., forms on jasper samples to be used for ornaments and jewelry (Figure 10). When the features of jasper, such as color composition, brightness, durability, being massive and large in size (reaching 50–60 cm), and being suitable for processing, are evaluated, it has been determined that they can be used as gemstones. The large sizes of jaspers in the study area may enable the production of functional items (coffee tables, tables, trays, etc.), as well as jewelry and accessories.

Figure 9. Raw (unprocessed), (**left**), and sliced, (**right**), forms of jasper samples taken from the study area.

Figure 10. Cabochon-processed jasper samples taken from the study area.

4. Discussion and Conclusions

The jaspers located in the Tepeyurt (Topçam) region were formed together with manganese ore as a result of hydrothermal activity within the late Triassic greenish-colored altered metavolcanic rocks. Jasper formations related to hydrothermal activity and metamorphism are also present within different parent rocks. When we look at other jasper formations in the world, [23] stated that the jaspilites in Ukraine were formed within iron-bearing sedimentary and volcanic rocks that have undergone metamorphism under green-colored amphibolite facies conditions. Additionally, [24], in their study examining the precious stones found in the Ugljarevac Vardar region, determined that jaspers were found in hydrothermally altered serpentinite stocks, and were formed in the first phase of hydrothermal activity. In [25] reported that there are thin jasper veins in the limestone borders containing iron and manganese around Szkalka Mountain, colored yellow with iron hydroxide and black with manganese, and they suggested that jaspers were formed by the crystallization of silica gel that settled in limestone fissures by iron hydroxide, iron, and manganese bicarbonate solutions. Similar to the jasper formations in the study area, [26] noted in his work titled 'Cuban Manganese Deposits' that red-gray or black jaspers are often associated with manganese ores, particularly those found in tuff deposits.

According to the results of the XRD analysis of jasper samples taken from the study area, the associations of quartz, hematite, and calcite minerals in jaspers were determined. In addition to these minerals, the presence of pyrite was also detected in the black and red parts of the jaspers. In their mineralogical investigations on jaspers, [27] determined quartz, moganite, limonite, hematite, dolomite, and mica minerals in the composition of their jaspers. As a result of their XRD analysis on jaspers seen in the Gaj–Lazin region, [28] revealed that jaspers consist of quartz, with a small amount of hematite, dolomite, smectite clay, and serpentine minerals.

As a result of the WDXRF analysis of jasper samples, it was determined that the amount of SiO_2 was 82.5%, the amount of Fe_2O_3 was 15.5%, the amount of CaO was 1.07%, the amount of MnO was 0.25%, the amount of Al_2O_3 was 0.28%, and the amount of MgO was 0.02%. In their analysis of jasper samples, [27] determined that the amount of SiO_2 was 95.41% and the amount of Fe_2O_3 was 4.80%. In their study on Dalmatian jasper samples, [29] determined that the amount of SiO_2 was 73.66%, the amount of Al_2O_3 was 10.74%, the amount of K_2O was 4.65%, and the amount of Fe_2O_3 was 4.09%. The amount of Fe_2O_3 in the jaspers from the study area is approximately three times higher than that reported in the aforementioned studies.

In [30] stated that Kittila jaspers contain less than 20% iron. In [31] stated that jaspers in the Orissa region of India have a red-banded structure due to the hematite in their composition. In [32] found that the blood-red color of Guilin region jaspers originates from hematite, and as the amount of hematite increases, the brightness of the red color increases. According to the ICP-MS analysis results of the jaspers in the study area, different color tones (white, red, black) were observed. In the white regions, the amounts of Fe (6975.49 ppm) and Mn (935.87 ppm) were found to be the lowest, while in the black regions, the amounts of Fe (96,431.07 ppm) and Mn (6040.40 ppm) were the highest. The Fe (46,893.90 ppm) and Mn (3219.71 ppm) amounts of the red region are at a value between the Fe and Mn amounts of the white and black regions. In contrast to the increasing amounts of Mn and Fe in the white, red, and black regions, a decrease in the amount of Cs was observed (white: 78,614.49 ppm; red: 36,836.48 ppm; black: 13,945.64 ppm). This indicates that the variation in the amounts of Fe, Mn, and Cs is the most significant factor contributing to the darkening of the white–red–black color tones.

The examined jaspers are appealing due to their hardness and durability, the inclusion of various color tones (white, red, black), spotted patterns, and high polishability, making them suitable for jewelry making. These features allow for unique jewelry designs and position these jaspers as sought-after raw materials on the market. The jasper samples collected from the study area are opaque, and cabochon cutting has been applied to better showcase their colors, resulting in ornamental stones suitable for use in jewelry. Additionally, the jaspers in the study area are found in large sizes (with diameters reaching 50–60 cm), enabling their use not only in jewelry production, but also in the creation of decorative and functional items (such as tables, trays, etc.). In addition, the study area has the potential to be operated in, and can contribute to the regional economy as a result.

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Conflicts of Interest: The authors declare no competing interests.

References

1. Kaydu Akbudak, İ.; Başıbüyük, Z.; Gürbüz, M. Silicified woods consist with malachite, azurite, and hematite in the Middle Eocene Çekerek Formation, Tokat—Turkey. *Lithol. Miner. Resour.* **2021**, *56*, 548–558. [CrossRef]
2. Başıbüyük, Z.; Akbudak, I.K.; Gürbüz, M. Mineralogical, geochemical and gemological investigation of Artova Ch-chalcedonies, Tokat–Turkey. *Gospod. Surowcami Miner.* **2020**, *36*, 77–92.
3. Candan, E.Ö.; Akbudak, İ.K.; Başıbüyük, Z.; Ekincioğlu, G. Mineralogical-Petrographical and Gemological Investigation of Tokat Nebiköy Chalcedony. *Turk. Geol. Bull.* **2022**, *65*, 287–296.
4. Başibüyük, Z.; Gürbüz, M.; Kaydu Akbudak, İ. Surprise eggs, the miracle of nature: Almus agates (Tokat–Turkïye). *Gospod. Surowcami Miner.* **2023**, *39*, 5–22.
5. Yüzbaşıoğlu, T.Y. Mineralogical-Petrographic Investigation and Gemological Properties of Tepeyurt (Tokat) Jaspers. Master's Thesis, Kırşehir Ahi Evran University, Institute of Science, Kırşehir, Turkey, 2020; p. 62.
6. Başıbüyük, Z. Mineralogical, geochemical, and gemological characteristics of silicic gemstone in Aydıncık (Yozgat–Turkey). *Arab. J. Geosci.* **2018**, *11*, 292. [CrossRef]
7. Kaydu Akbudak, İ.; Başıbüyük, Z.; Gürbüz, M. Investigation of mineralogy-petrography and economics of Yozgat "Aydıncık" chalcedony-amethyst formations. *Dicle Univ. Fac. Eng. J. Eng.* **2018**, *9*, 313–324.
8. Fernie, W.T. *The Occult and Curative Powers of Precious Stones*; Rudolph Steiner Publications: Blauvelt, NY, USA, 1973.
9. Petrov, V.P.; Bogatikov, O.A.; Petrov, R.P. *Petrographical Dictionary*; Nedra: Moscow, Russia, 1981.
10. Kostov, I.R. Review of the Mineralogical Systematics of Jasper and Related Rocks. In *Archeometrial Mühely*; 2010; pp. 209–214. Available online: https://www.academia.edu/1122501/Review_on_the_mineralogical_systematics_of_jasper_and_related_rocks (accessed on 15 May 2020).
11. Zaba, J. *The Illustrated Encyclopedia of Minerals and Rocks*; VideoGraf II: Chorzow, Poland, 2010; p. 503.
12. Lazzarelli, H.N. Blue Chart Gem Identification. 2010. Available online: http://www.gembluechart.com (accessed on 10 March 2020).
13. Schumann, W. *Gemstones of the World*; Robert Hale Ltd.: London, UK, 2001.
14. Barsonav, G.P.; Yakovleva, M.E. *Mineralogy of Jaspers from the USSR*; (Ural, Altai), Nauka: Moscow, Russia, 1978; p. 88.
15. Kievlenko, E.Y. *Prospecting and Evaluation of Deposits of Gem and Decorative Stones*; Nedra: Moscow, Russia, 1980; p. 263.
16. Putolova, L.S.; Menchinskaya, T.I.; Baranova, T.L.; Vdovenko, A.P. *Decorative Varieties of Coloured Stone in the USSR*; Nedra: Moscow, Russia, 1989; p. 272.
17. Kunz, F.G. *The Curious Lore of Precious Stones*; Dover Publications: New York, NY, USA, 1971.
18. Atmann, J. *Gem and Stone: Jewelry of Earth, Sea, and Sky*; Chronicle Books: San Francisco, CA, USA, 2012.
19. MTA 1/500.000 Scale Geological Map of Turkey, General Directorate of Mineral Research and Exploration, Ankara. 2002. Available online: https://www.mta.gov.tr/en/maps/geological-500000 (accessed on 21 February 2020).
20. MTA 07-40-JHS-01-H37a1 Sheet 1/25.000 Scale Geological Map. Available online: https://www.mta.gov.tr/en/maps/geological-100000 (accessed on 15 January 2024).
21. Ekincioğlu, G. Non-destructive methods determination of thermal shock resistance of natural building stones applicated with different water repellent chemicals on their surfaces. *Gospod. Surowcami Miner. Miner. Resour. Manag.* **2023**, *39*, 81–101.
22. Ekincioğlu, G.; Akbay, D. Estimation of Specific Cutting Energy and Noise Level in Circular Saw Cutting Process by Leeb, Shore and Schmidt Hardness Values of Rocks. *J. Min. Sci.* **2023**, *59*, 368–379. [CrossRef]
23. Baranov, P.; Shevchenko, S.; Heflik, W.; Natkaniec-Nowak, L.; Dumanska-Slowik, M. Jaspilite—The gemstone of Ukraine. *J. Gemmol. Proc. Gemmol. Assoc. Great Br.* **2009**, *31*, 163–169. [CrossRef]
24. Kuresevic, L.; Vusovic, O.; Delic-Nikolic, I. Geology of gemstone deposit Ugljarevac (Central Serbia) and contributions to genetic model. *Geol. Maced.* **2017**, *1*, 67–76.
25. Koch, S.; Grasselly, G. The Manganese Ore Mineral Occurrences of Hungary. *Acta Min. Peti. Univ. Szegediensis* **1951**, *5*, 1–14.
26. Park, C.F. Manganese deposits of Cuba. In *Geologic Investigations in the American Republics*; Bulletin 935-B; United States Department of the Interior: Washington, DC, USA, 1941; pp. 75–97.
27. Arık, F.; Özen, Y. Mineralogical-petrographical, geochemical properties and use of jasper formations in Tokat region as gemstone. *Niğde Ömer Halisdemir Univ. J. Eng. Sci.* **2020**, *1*, 451–460.
28. Kuresevic, L.; Devic, S. Mineralogical and geochemical characterization of silica-carbonate gemstone veins from Gaj-Lazine (Central Serbia). *Geol. Maced.* **2015**, *2*, 177–182.
29. Powolny, T.; Dumanska-Slowik, M. True colors of "Dalmatian Jasper". *Notes New Tech. Gems Gemol.* **2017**, *53*, 325–331. [CrossRef]
30. Kinnunen, K.A. Primary sedimentary features in Kittila jasper Finnish Lapland. *Bull. Geol. Soc.* **1982**, *1–2*, 69–76. [CrossRef]
31. Mallik, S.B.; Sherwood, G.J.; Das, K. The Magnetic Mineralogy of the Precambrian Banded Haematite Jasper Formation, Orissa, India. *J. Geomag. Geoelectr.* **1992**, *1*, 155–165. [CrossRef]
32. Liu, C. Gemological Characteristics of Guilin "Chicken-Blood-Red Jasper". *Guilin Gongxueyuan Xuebao/J. Guilin Univ. Technol.* **2010**, *30*, 223–228.

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