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Red jasperoids from the area of the Ukrainian Antarctic research station

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Червоні яшмоїди з району Української антарктичної станції «Академік Вернадський»

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Red jasper-like rocks from the area of the Akademik Vernadsky Station are known since the time of the first Ukrainian Antarctic expeditions. But until now, all the published information about them was limited to only one brief mention in the abstract of the report by Mytrokhyn and Bakhmutov (2017). This article summarizes all available data about these jasperoids with the aim of clarifying their origin and systematic position among other rocks of essentially siliceous composition. The authors studied the manifestations of the jasperoids on the Argentine Islands and Jalour Islands near the western coast of the Kyiv Peninsula (Graham Coast of the Antarctic Peninsula). It was found that small vein-like bodies of the jasperoids occur in Jurassic-Cretaceous strata of the Antarctic Peninsula Volcanic Group. According to their geological position, mode of occurrence and petrographic features, they are quite similar to hematite jasperoids found in many parts of the world in association with hydrothermal deposits of Au, Cu, Pb, Zn, Sb and Hg. The authors prove a hydrothermal origin for new localities of hematite jasperoids discovered in the Antarctica. Results of the studies indicate that the jasperoids were formed from silica-enriched hydrothermal fluids. Low temperature hydrothermal process was taking place at a shallow depth. Silica was mainly in a form of colloidal solution namely as silicic acid gel. The presence of hematite as well as some other minor minerals (calcite, pyrite, epidote, sericite and chlorite) can be explained by the interaction of the hydrothermal fluids with host rocks. It is assumed that the fluids were of juvenile origin. They could separate from the granitoid intrusion which lies at depth below hydrothermally altered volcanogenic strata. Zones of increased fracturing in the host volcanites were feeding channels for rising fluids.

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Introduction

The red jasper-like rocks from the area around the Ukrainian Antarctic station (UAS) are known primarily to a narrow group of specialists who have worked in this region. Few samples of these intriguing rocks can be seen on shelves in the station's premises or in specialized scientific collections. Their vivid colouring attracts the attention of both scientists and technical staff, who commonly refer to these beautiful stones as «jasper» although such name is not entirely accurate. It is still not known who first discovered the primary outcrops of red jasperoids. Published works by British geologists make no mention of them (Elliot, 1964; Curtis, 1966; Hawkes, Littlefair, 1981). However, interviews with our countrymen polar explorers revealed that at least two localities of "red jasper" have been known since the early Ukrainian Antarctic expeditions. Nevertheless, an analysis of appropriate publications shows that the first and only printed mention of red jasperoids in the UAS area appeared only in 2017. Specifically, the presence of red jasperoids in the volcanites of Uruguay and Yalour Islands is briefly mentioned in the VIII International Antarctic Conference abstract by O.V. Mytrokhyn and V.G. Bakhmutov. Laboratory studies demonstrated that samples from these and newly discovered outcrops of the jasperoids reveal certain petrographic specificity for each their localities. The results were partly included in A.R. Kryzhanovska's master's thesis (2023), the materials of which remain unpublished. These as well as other unprocessed materials formed the basis for further research which included optical polarization microscopy, scanning electron microscopy and electron microprobe analysis. This article summarizes all available data on the geological position, mode of occurrence and petrographic features of the red jasperoids in the UAS area to clarify their origin and systematic position among other rocks of significant siliceous composition.

Geological position of red jasperoids

All identified localities of red jasperoids are found on the Argentine Islands or on nearby Yalour Islands. Both island groups are located off the western coast of the Kyiv Peninsula, which is part of the Graham Coast of the Antarctic Peninsula. In both cases the jasperoids occur as small vein-like bodies within Mesozoic orogenic calc-alkaline volcanites. These volcanites are divided into the Argentine Islands Formation (AIF) and the Kyiv Peninsula Formation (KPF). These volcanic formations belong to the Antarctic Peninsula Volcanic Group (APVG) which formed along an Andean type continental margin during the Jurassic-Paleogene. The development areas of the AIF and KPF are bounded by two adjacent tectonic blocks, separated by the northeast-trending Penola Strait fault (Fig. 1).

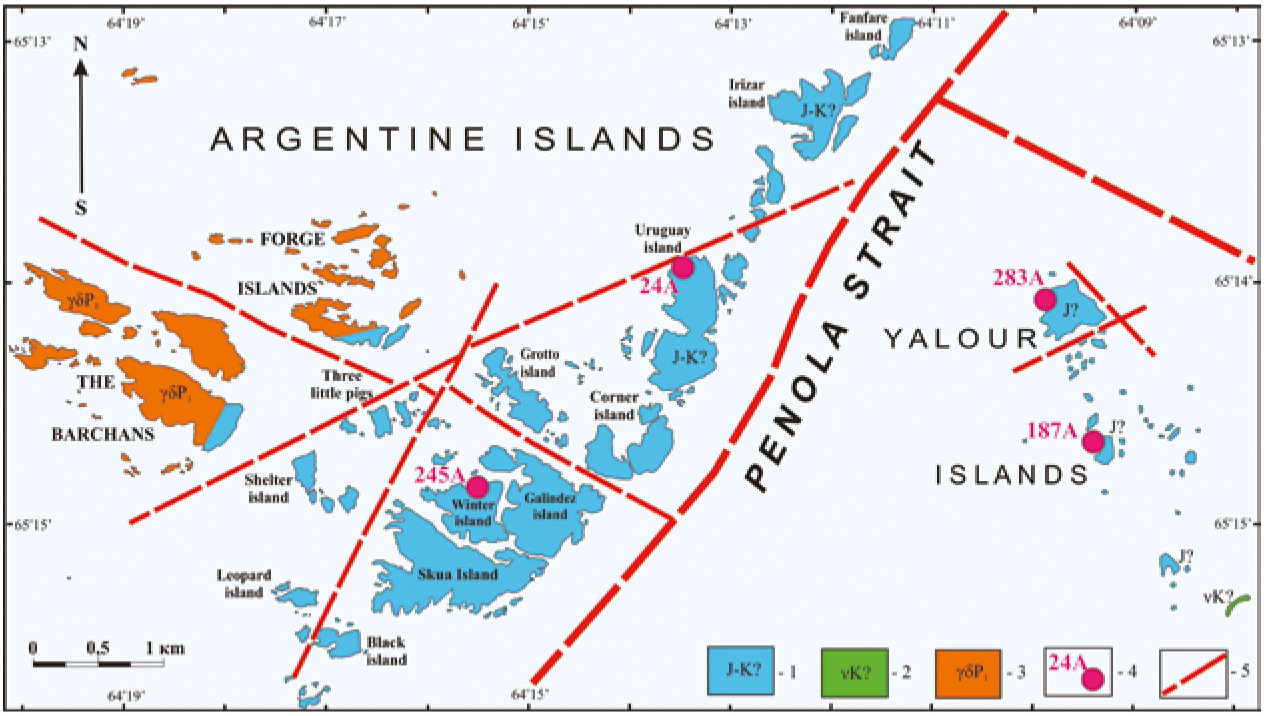

Fig. 1. Schematic geological map of the area of distribution of the red jasperoids, compiled by O.V. Mytrokhyn. Legend: *1* – Mesozoic volcanic strata on the Argentine Islands (J-K?) and on the Yalour Islands (J?); *2* – gabbroids on the Yalour Islands; *3* – Paleocene granitoids on the Barchans and Forge Islands; *4* – outcrops of the red jasperoids with corresponding numbers of their localities; *5* – faults

The Jurassic-Cretaceous volcanites of AIF are widespread on the eastern part of the Argentine Islands. They consist of andesites, dacites, lapilli tuffs and ash tuffs as well as pyroclastic breccias and tuff breccias. A smaller amount of tuffites, sandstones, siltstones and siliceous rocks have also been found. All of these rocks are subject to varying degrees of contact-thermal metamorphism caused by the Paleocene Barchans-Forge granitoid intrusion or by Cretaceous sill-like microdiorite intrusions. Intrusive magmatism may also be associated with local hydrothermal-metasomatic alterations in the volcanites namely propylitization, sericitization and silicification. The primary stratification of the AIF is disrupted by tectonic deformations. The identified stratification elements show steep or even vertical dips. Their strike varies from predominantly northeast to subordinate northwest. Additionally, the stratigraphic column is complicated by local block displacements along a diagonal system of faults. In some places, sub-latitudinal and sub-meridional fault systems are also developed. Mafic dyke swarms are controlled by diagonal and sub-meridional faults. It is known that dykes intruded into the volcanics in at least two stages namely Mesozoic and Cenozoic ones.

The geological study of the Yalour Islands remains less detailed compared to the Argentine Islands. Most of the Yalour Islands are composed of volcanites that can be preliminarily correlated with the Jurassic volcanic formation spread on the adjacent coast of the Kyiv Peninsula. Gabbroids were found only on one of the Yalour Islands, located at the extreme south-eastern flank of this island group. It is assumed that they belong to the Tuxen-Rasmussen gabbroid intrusion of Early Cretaceous age. This intrusion is exposed further east on the Cape Tuxene and Waddington Bay of the Kyiv Peninsula (Mytrokhyn et al., 2017). The volcanites of the Yalour Islands include lapilli tuffs of dacitic composition as well as dacitic lavas. Similar to the AIF, they are subject to contact-thermal metamorphism, hydrothermal-metasomatic alterations and some tectonic deformations. Satellite images show that the shoreline configuration and relief of the Yalour Islands are controlled by diagonal and sub-meridional fault systems. In addition, a sub-latitudinal system of tectonic fractures is developed in the volcanites.

Mode of occurrence and petrographic features of the red jasperoids

Red jasperoids on the Uruguay Island

Locality 24A (65°13’57,7“S, 64°13’27,9’’W) is on the northern near-summit part of the Uruguay Island (Fig. 2). This outcrop of jasperoids was first discovered by V.G. Bakhmutov in 1996 and further was studied by G.V. Artemenko in 2010. But the results were not published. Then it was visited and described by O.V. Mytrokhyn in 2017. The red jasper-like rock occurs as a small vein that intersects hydrothermally altered pyroclastic rocks. These belong to the AIF volcanites. The maximum thickness of the jasperoid vein is 6 cm. It can be traced over a distance of 3 meters before its disappearing under permanent snow-ice cover. The vein falls subvertically extending from west to east at an azimuth of 95°. A similar sublatitudinal orientation is found in one of the tectonic fracture systems within the surrounding volcanites. Another system of tectonic fractures shows northeast orientation that aligned with the regional fault of the Penola Strait. The red jasperoid contacts with dark gray lithoclastic tuff of dacitic composition in sample 17-24A-1. The boundary between them is sharp and wavy with a reddish-brown alteration zone approximately 5 mm thick on the tuff side. Small angular fragments of altered tuff, up to 2 cm in size, are embedded in the aphanitic matrix of the jasperoid giving it a taxitic structure. In thin section the jasperoid reveals heterogeneous spotted texture with uneven fine- to microcrystalline quartz aggregates that are visible under cross polarized light. Tiny grains of the quartz that make up the bulk of the rock are isometric with jagged boundaries. Microfibrous chalcedony aggregates are present but rare. Relic colloform texture of the jasperoid can be revealed by morphology of the hematite microcrystalline aggregates and their distribution visible in plane polarized light. The main rock-forming minerals are quartz and hematite. Chlorite, sericite and epidote are present in subordinate amounts. Single grains of spessartine garnet were identified by electron microprobe analysis.

Red jasperoids on the Winter Island

Locality 245A (65°14,870’S, 64°15,564’W) is on the northern shore of Winter Island (Fig. 3). This location of jasperoid was discovered by O.V. Mytrokhyn in 2019 and he described it in 2020.

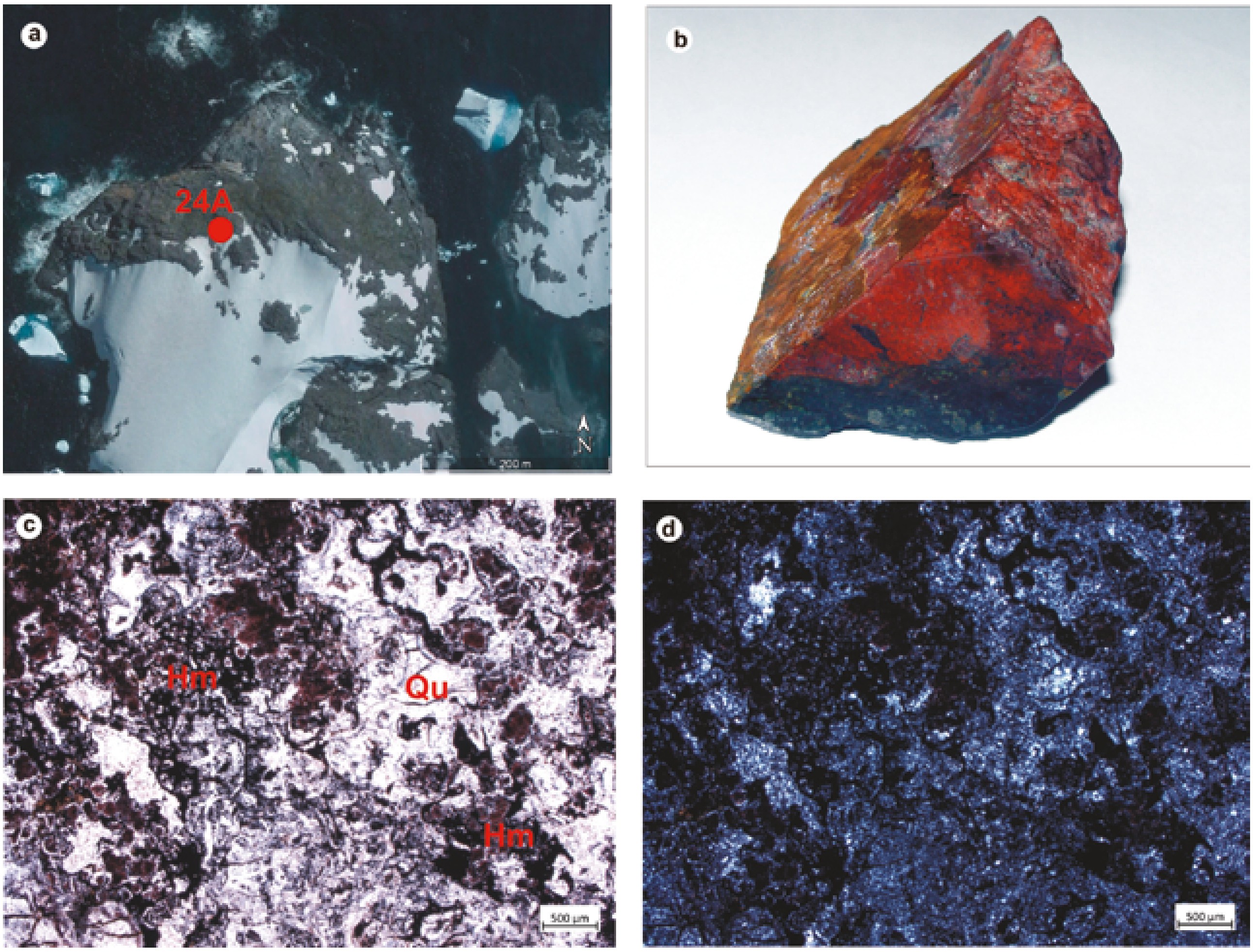

Fig. 2. Red jasperoids on the Uruguay island: *a* – Google Earth space image of locality 24A; *b* – appearance of the sample No. 17-24A-1, size 7×6 cm; *c–d* – photomicrograph of thin section No. 17-24A-1 in plane polarized and cross polarized light, Qu – quartz, Hm – hematite

Hydrothermally altered porphyritic andesites of the AIF are exposed here on the shore of a small bay within the tidal zone. There are numerous phenocrysts of altered plagioclase, about 2–3 mm in size, in the greenish-gray aphanitic matrix of the andesites. A taxitic structure is evident due to the presence of irregular inclusions (lithoclasts) of 10–20 cm, made up of more altered andesite. These inclusions are insufficient to classify the host rock as pyroclastic. The andesites are intersected by irregular veins of red jasper-like rock. These veins demonstrate a wavy configuration, limited extent and variable thickness, reaching 10–15 cm in swellings. Visually noticeable hydrothermal mineralisation is associated with jasperoid veins. Pyrite typically concentrates at the boundaries between the jasperoid and the host andesite. Epidote is distributed everywhere. Thin red jasperoid veinlets cross the greenish-gray porphyritic andesite in sample 20-245A-1. Pyrite crystals of 1–2 mm are scattered unevenly in the aphanitic matrix of the jasperoid. Beside them small angular inclusions of host andesite are visible in one place. In thin section we can see that the main rock-forming minerals of the jasperoid are quartz and hematite. They form uneven fine- to microcrystalline mass with a granoblastic texture varying from mosaic to jagged. Relic colloform texture is somewhat less pronounced than in the Uruguay Island jasperoid, with no chalcedony present. Notably, unlike the previous locality, the jasperoid on Winter Island shows higher content of epidote. It crystallizes as individual grains and aggregate clusters. Subordinate pyrite and chlorite are present beside epidote. Idiomorphic pyrite crystals and their clusters crystallize in both endo- and exocontact zones of the jasperoid veinlets as well as around rock inclusions of the host andesite.

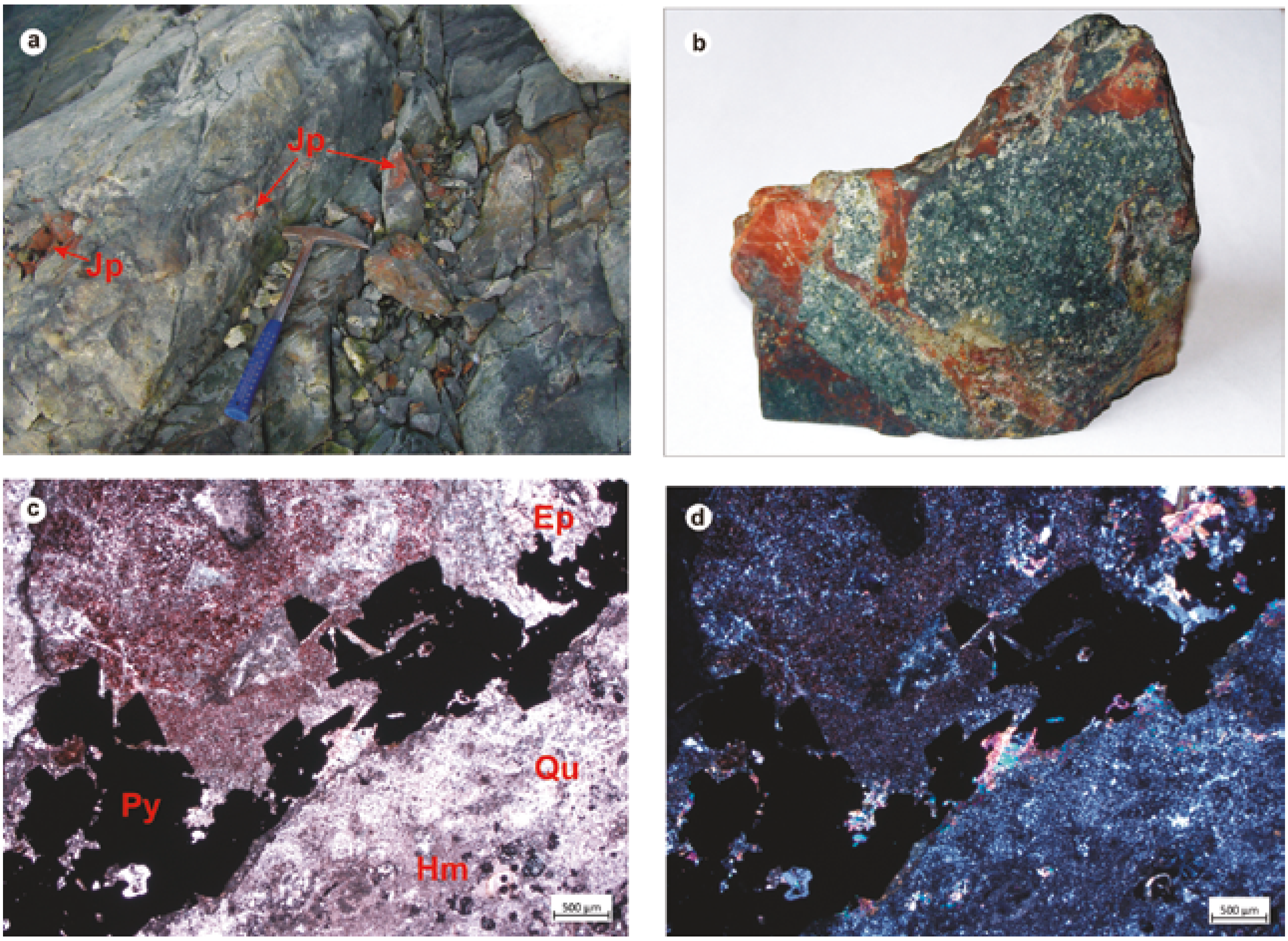

Fig. 3. Red jasperoids on the Winter island: *a* – mode of occurrence of jasperoids (Jp) at locality 245A; *b* – appearance of the sample No. 20-245A-1, size 9×8,5 cm; *c–d* – photomicrograph of thin section No. 20-245A-1 in plane polarized and cross polarized light, Qu – quartz, Hm – hematite, Py – pyrite, Ep – epidote

Red jasperoids on the Yalour-I Island

There are several outcrops of jasperoids on the largest and most frequently visited island among the Yalour group. They are noted by many observers. For instance, R.O. Bratchik was a radio-operator in the 1st and 2nd Ukrainian Antarctic expedition who reported seeing 'jasper' on the Yalour Islands during wintering 1995–1998. But he did not specify on which island and where exactly. Similarly, geophysicist Y.F. Nakalov observed 'red jasper' on the Yalour Islands during seasonal work in 2001 and he also could not remember the exact location. More precise information was provided by V.R. Morozenko, a geologist with a seasonal team, who in 2003 discovered and examined several veins of 'red jasper' on the largest of the Yalour Islands. These veins were located on the island's western shore, near a colony of Adélie penguins. The largest jasperoid vein was about 6 cm thick with an approximately meridional (?) orientation. Several samples of red jasperoid and the surrounding rock were collected by V.R. Morozenko from this exposure. O.V. Mytrokhyn and V.G. Bakhmutov visited this jasperoid outcrop in 2017. Due to unsatisfactory exposure conditions they managed to locate only one thin jasperoid vein. It intersects hydrothermally altered pyroclastic rocks that likely belong to the KPF. The strike of the jasperoid vein corresponded to a system of sublatitudinal fractures that cross the entire island and aligns with the jasperoid occurrence on Uruguay Island. Tectonic fracturing with a northeast strike on Yalour-I Island is less pronounced. Red jasperoid is in contact with greenish-gray lithoclastic dacite tuff in sample 03-283A-1 (Fig. 4). The boundary between them is sharp, undulating, with thin jasperoid veinlets penetrating the tuff near the contact. The jasperoid contains small, flattened inclusions of the tuff that are oriented subparallel to the contact. Unlike the jasperoids described above, this sample is not as monolithic.

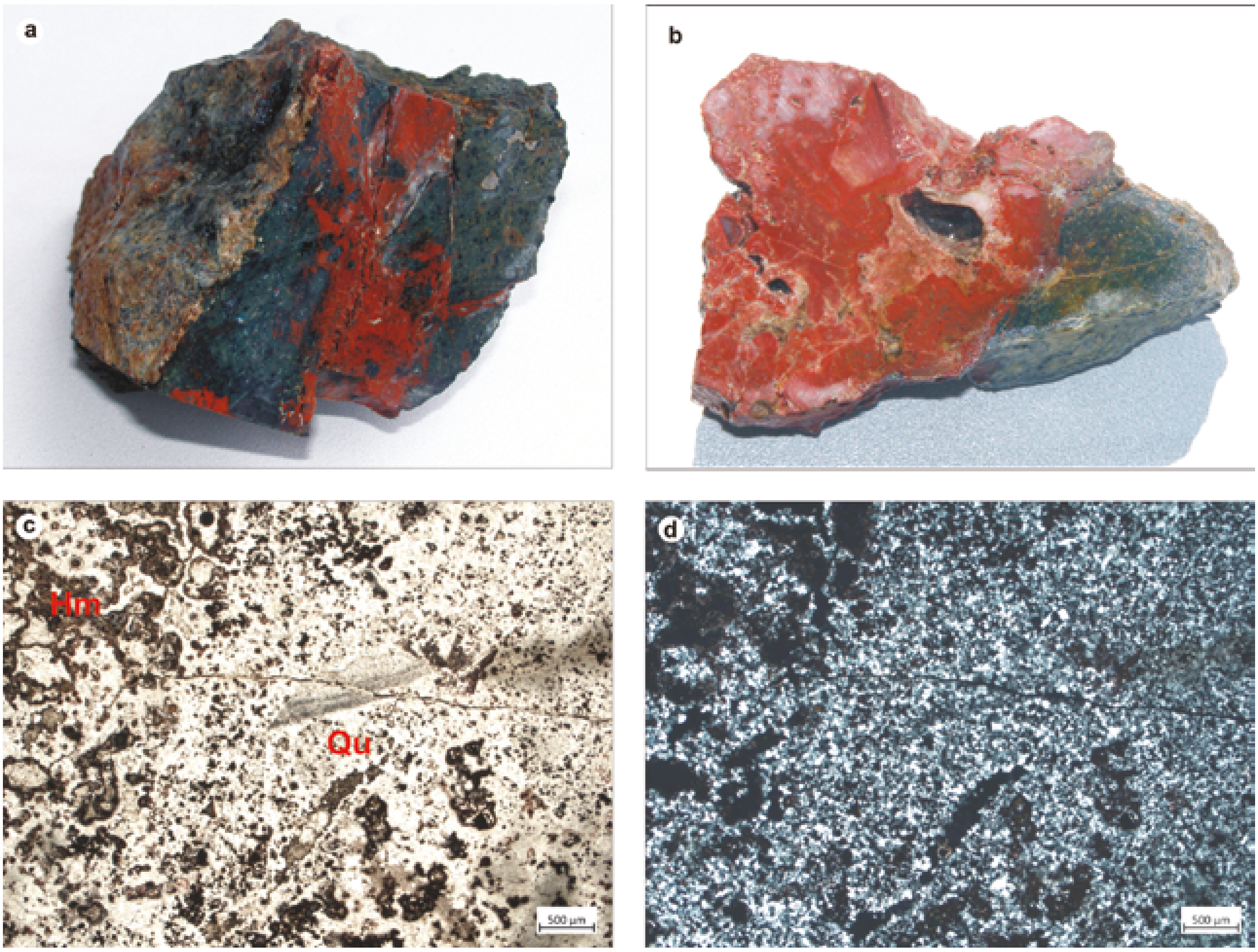

Fig. 4. Red jasperoids on the Yalour-I Island, locality 283A: *a* – small jasperoid veinlet in volcanic tuff, the sample No. 03-283A-2, size 7×5 cm; *b* – appearance of the sample No. 03-283A-1, size 7×5 cm; *c–d* – photomicrograph of the thin section No. 03-283A-1 in plane polarized and cross polarized light, Qu – quartz, Hm – hematite

Firstly, it is intersected by a dense network of thin, sinuous veinlets of milky quartz. Secondly, there are numerous irregular cavities in Yalour-I jasperoid, ranging in size from 1–2 mm to 1.5 cm. They are encrusted with tiny quartz crystals. In thin section, this jasperoid exhibits uneven fine- and microcrystalline texture similar to the samples described above. The main rock-forming minerals are quartz and hematite. Typical subordinate mineral are sericite and chlorite. There is an accessory amount of pyrite. Its grains are replaced by iron oxides and iron phosphates at the edges. However, Yalour-I jasperoids differ from Uruguay and Winter Island samples in details. In particular, Yalour-I jasperoid shows an irregular mottled pattern alternating between areas of relict colloform texture and areas where it is absent. In the latter areas, the texture is defined as a granoblastic mosaic, as the quartz grains generally lack the jagged boundaries typical of Uruguay Island jasperoid. In areas with colomorphic structure, chalcedony occurs alongside granoblastic quartz, forming the outer layers of concentrically zoned aggregates. Additionally, the red jasperoid from Yalour-I shows elements of a relict clastic, possibly cataclastic, texture. A few fragments of older-generation jasperoid are distinguishable within its matrix in thin section. This earlier jasperoid is thinly layered and it exhibits the finest microcrystalline texture. Most grains of the granoblastic quartz are intersected by a tissue of thin hematite-filled fractures.

Red jasperoids on the Yalour-II Island

Two localities of the red jasperoids were discovered by O.V. Mytrokhyn on the second-largest island of the Yalour group in 2019. One of them is locality 187A (65°14,656'S, 64°9,339'W) on the western shore of the Yalour-II Island. Smoothed by marine abrasion volcanic rocks are exposed here

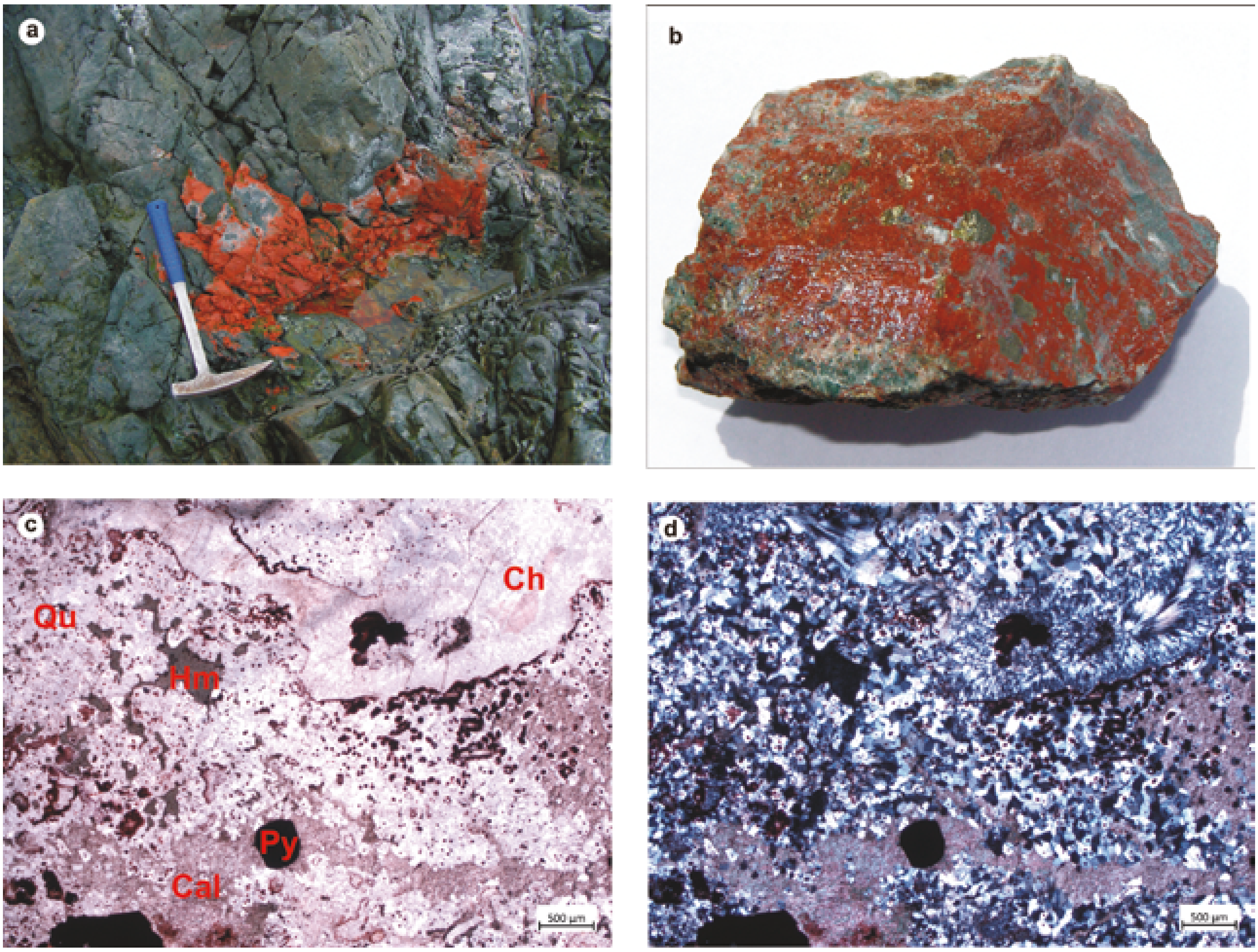

Fig. 5. Red jasperoids on the northern part of the Yalour-II Island: *a* – mode of occurrence of the jasperoids in the volcanic tuffs; *b* – appearance of the sample No. 19-187A-4, size 7×4 cm; *c–d* – photomicrograph of the thin section No. 19-187A-4 in plane polarized and cross polarized light, Qu – quartz, Ch – chalcedony, Hm – hematite, Py – pyrite, Cal – calcite

along the shore of a small bay. These volcanites are presumed to belong to the KPF. Outcrops range in height from 2–3 to 5–6 m, extending over a length of at least 50 m. The volcanic rocks are represented by hydrothermally altered dacites. Striped greenish coloration displays their fluidal texture. The layers, varying from 3–4 to 10 mm in thickness, differ in colour intensity. Layer boundaries are somewhat diffuse and wavy. The layers themselves are not very long. They often wedge out along their strike. Layering is emphasized by the orientation of small secondary cavities and tiny phenocrysts of altered plagioclase. The layering dips steeply to the south at an angle 75° with the strike azimuth of 260°. Thin sinuous quartz veins cross-cut the layering in one place where they associated with tectonic fracturing of a submeridional strike. These veins consist of light gray brecciated quartz within which small crystal clusters of calcite, dissemination of pyrite and fine-grained hematite are unevenly distributed. A bright red jasperoid-like rock is formed in areas of maximum hematite concentration. Irregular cavities give a cavernous texture to the selvages of thin mineralized veins. An irregular banded distribution of mineral infilling is observed within the studied veins in some places. Besides the described area, bright red jasper-like rocks form numerous vein-like segregations on the northern shore of the Yalour-II Island. They cross pyroclastic rocks of dacitic composition (Fig. 5). Sample 19-187A-4 is represented by red jasperoid with large crystal dissemination of pyrite and calcite within its aphanitic matrix. Idiomorphic pyrite crystals, 2–4 mm in size, take the shape of pentagonal dodecahedrons. Larger irregular crystal grains of light-gray calcite are also present. Quartz and hematite are identified as the main rock-forming minerals in the thin section of the jasperoid. They form fine- and microgranoblastic aggregates that retain relict colloform texture in many areas.

Later fan-shaped aggregates of fibrous chalcedony are widespread. Pyrite, calcite and chlorite are present in subordinate amounts. Besides the large crystals, fine-grained pyrite is also widespread. Both types of pyrites crystallized after hematite. Calcite, on the other hand, consistently crystallizes as fairly large xenomorphic grains with poikilitic texture, indicating its latest crystallization phase.

Discussion

The data obtained allow for several generalizations regarding to geology and petrology of the red jasperoids in the Ukrainian Antarctic Station area, which, in turn, enables their origin and systematic classification among other siliceous rocks to be determined.

The common characteristics of all studied localities of the jasperoids are: 1) their localization in volcanogenic strata belonging to the Antarctic Peninsula Volcanic Group; 2) spatial association with aureoles of low-temperature hydrothermal alterations in volcanic rocks; 3) discordant mode of occurrence in the form of small, vein-like bodies located in zones of fracturing and tectonic brecciation; 4) uneven fine- and microcrystalline textures with elements of relict colloform texture; and 5) predominantly hematite-quartz mineral composition. All of these features provide clear evidence for the hydrothermal origin of the red jasperoids in the UAS region. Consequently, the term ‘jasper’ is inappropriate for these rocks. True jaspers are sedimentary siliceous rocks with chemogenic or mixed biochemogenic origin. Various authors have used the terms ‘jasperoid’ or the broader name ‘jasper-like rock’ to describe hydrothermal-metasomatic siliceous rocks that resemble jasper in appearance. The term ‘jasperoid’ was first introduced by J. Spurr in 1898. An extensive description of jasperoids from various regions in the United States was provided by Lovering in 1972. In soviet-time scientific publications, different authors referred to them as ‘jasperoids’ or ‘jasper-like rocks’. However, over time, the term jasper-like’ became overly broad and ambiguous. For instance, ‘jasper-like’ is often used in preliminary field identification to denote any rock resembling jasper. Alternatively, jasper-like rocks are those siliceous ones with a non-sedimentary origin, as opposed to true jaspers. Lastly, some use the terms ‘jasperoid‘ and ’jasper-like rock‘ interchangeably. In modern English-language geological literature, jasperoids refer to siliceous, jasper-like rocks that form through hydrothermal-metasomatic transformation of dolomites, limestones, and certain volcanic rocks. The name derives from the English term ’jasper‘. Despite their visual similarity to jaspers, jasperoids differ from true sedimentary jaspers not only in origin but also in peculiarities of formation, as well as in some aspects of texture and composition. Jasperoids are found worldwide, and geologists have shown significant interest in them due to their association with hydrothermal deposits of Au, Cu, Pb, Zn, Sb, and Hg (Wilborn, 2017; Bootorabi et al., 2020; Hoof et al., 2020; Madondo et al., 2021).

The authors of this paper prefer the term ‘jasperoid’, as commonly accepted in Western literature, applied in a narrow specialized sense namely siliceous rocks with hydrothermal or hydrothermal-metasomatic origins. Judging by the identified mineral composition, the origin of hematite jasperoids in the UAS area is likely associated with silica-rich hydrothermal fluids. The relict colloform texture indicates that silica was predominantly in the form of a colloidal solution i. e. silicic acid gel. This suggests a low-temperature hydrothermal process occurring at shallow hypabyssal or subvolcanic depths. More precise P-T conditions for jasperoid formation should be determined through further mineralogical studies, particularly fluid inclusion analysis. The typical presence of hematite in the studied jasperoids does not necessarily indicate Fe^{3+} in the parent fluid. Iron could have been leached from the surrounding volcanic rocks in acidic conditions. Additional evidence for the influence of surrounding rocks on the composition of hydrothermal fluids is found in the specific mineralogical composition identified at each studied locality of hematite jasperoids in the UAS region. Currently, data on the primary source of the hydrothermal fluids that formed the hematite jasperoids are insufficient. Based on their vein-like occurrence and association with fault zones, it is plausible to assume that the fluids rose from a certain depth, utilizing zones of increased fracturing as conduits. Thus, it can be preliminarily assumed that these fluids have a juvenile origin and likely separated from a granitoid intrusion lying beneath the hydrothermally altered volcanogenic strata. This could be a deep continuation of the Paleocene Barchans-Forge granitoid intrusion, which outcrops in the western part of the Argentine Islands. Alternatively, it could be an older granitoid intrusion similar to the Early and Late Cretaceous granites, exposed 1.5–3 km east of the Yalour Islands on the Kyiv Peninsula coast. Isotopic dating of studied jasperoids in the future will help address this question as well.

Conclusions

1. All studied locations of the red jasper-like rocks are of hydrothermal origin. According to their geological position, mode of occurrence and petrographic features, they are quite similar to hematite jasperoids found in many parts of the world in association with hydrothermal deposits of Au, Cu, Pb, Zn, Sb and Hg.
2. The jasperoids in the UAS area were formed from silica-enriched hydrothermal fluids. Low temperature hydrothermal process was taking place at a shallow depth. Silica was mainly in a form of colloidal solution namely as silicic acid gel.
3. The presence of hematite as well as some other minor minerals (calcite, pyrite, epidote, sericite and chlorite) can be explained by the interaction of the hydrothermal fluids with host volcanic rocks.
4. Parental hydrothermal fluids were juvenile origin. They could separate from the granitoid intrusion which lies at depth below hydrothermally altered volcanogenic strata. Zones of increased fracturing in the host volcanites were feeding channels for rising fluids.

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Невеликі жилоподібні тіла червоних яшмоподібних порід залягають у мезозойських вулканогенних товщах на Аргентинських островах та островах Ялур біля західного узбережжя півострова Київ (Берег Греяма Антарктичного півострова). За умовами залягання, особливостями будови та мінеральним складом вони цілком подібні до гематитових джаспероїдів, відомих у багатьох куточках світу в асоціації з гідротермальними рудами Au, Cu, Pb, Zn, Sb, Hg. Автори доводять гідротермальне походження нових проявів гематитових джаспероїдів, виявлених в Антарктиці. Результати виконаних досліджень свідчать про те, що ці джаспероїди сформувалися зі збагачених на кремнезем гідротермальних флюїдів. Низькотемпературний гідротермальний процес відбувався на незначній глибині. Кремнезем знаходився переважно у вигляді колоїдного розчину – гелю кременекислоти. Присутність гематиту, а також деяких інших другорядних мінералів (кальциту, піриту, епідоту, сериციту та хлориту) може пояснюватись взаємодією гідротермальних флюїдів з вмісними породами. Припускається, що флюїди мали ювенільне походження та могли відокремитися від гранітоїдної інтрузії, яка залягає на глибині під гідротермально зміненими вулканогенними товщами. Живлячими каналами для флюїдів слугували зони підвищеної тріщинуватості у вмісних вулканітах.

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