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Geology

New Data on Formation of Goderdzi Petrified Wood (Georgia)

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(Presented by Academy Member David Shengelia)

ABSTRACT. Petrified wood of the Goderdzi Petrified Forest was formed due to crystallization of the low-temperature hydrothermal solutions following the activity of volcanicity. The hydrothermal solutions, generally rich in silica, circulated fluently through the channels of linear-fibrous cells of the petrified wood where the process of silicification developed in several stages. On the surface of the plate of horizontal (transverse) section of the petrified wood sample annual light and dark parallel stripes of the wood growth are visually (macroscopically) distinctly observed while gemological and polarizing microscopic investigations show that besides the annual light and dark parallel stripes of the wood growth there are clearly seen white and dark thinnest parallel stripes distributed almost orthogonally towards them; the channels of linear-fibrous cells of the petrified wood are completely filled up with the quartz group minerals crystallized at various temperatures. On the surface of the plate of vertical (radial and tangential) section of the petrified wood sample annual light and dark ordered parallel thin strips of wood growth are visually (macroscopically) distinctly observed while gemological and polarizing microscopic investigations reveal thinnest parallel lines coinciding them. At the initial stage of silicification of the petrified trees holocrystalline quartz was formed, at the intermediate stage the fibrous quartz and chalcedony and at the final stage of crystallization the low-temperature microcrystalline α-cristobalite and α-tridymite were crystallized. Taking into account the mineral diversities formed during the process of silicification it can be assumed that the process of petrified wood crystallization was developing within 250-130°C temperature interval. *© 2019 Bull. Georg. Natl. Acad. Sci.*

Key words: petrified wood, quartz, chalcedony, cristobalite, α-tridymite

Petrified wood of the Goderdzi Petrified Forest is developed in pyroclastolites (breccia, ash pelitic tuffs) of volcanogenic rocks [1] but fossilized flora [2] occurs in the Goderdzi suite white-greyish tufogenic series consisting of the alternation of tuff, breccia, conglomerates and basaltic lava beds. The thickness of the petrified wood series reaches 250m and sometimes even more. In some cases the trees with their roots retain vertical position and some fallen or inclined stems also occur. The rock is full of the stems and leaves imprints in all directions; sometimes leaves are even twisted.

The age of volcanic rocks containing the Goderdzi petrified wood does not exceed Middle-Miocene – Lower Pliocene (Cimmerian) and is dated as 5-7 million years old [3].

For detailed research of peculiarities of the crystallization process developed in the petrified wood we studied thin plates from the samples 3-Go and 27-Go in three mutually orthogonal directions: one – transversal (horizontal) and two vertical (one is radial and the other is orthogonal to it – tangential).

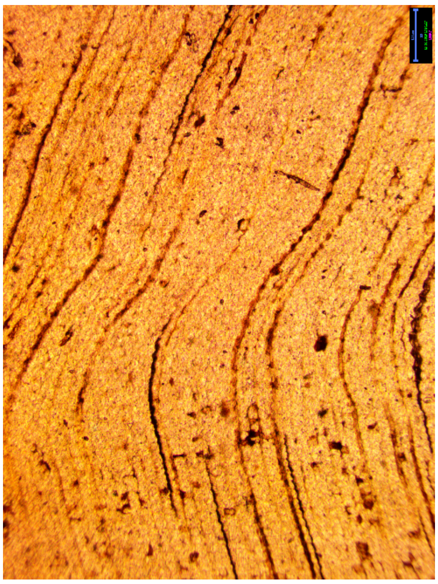
These plates were studied using petrographic, X-ray diffraction and X-ray fluorescence methods of analysis. According to the data of macroscopic, gemological and polarizing microscopic investigations, in petrified wood samples besides the distinctly outlined annual light and dark parallel zones of wood growth the white and dark thinnest parallel lines distributed almost orthogonally towards them were distinguished.

As a result of the conducted integrated laboratory studies the authors established the stages of formation of petrified wood, SiO_2 modifications developed in this process and the sequence of their formation: quartz, chalcedony, microcrystalline α-cristobalite and α-tridymite and opaline tridymite-crystobalite phases.

The silicification of Goderdzi petrified trees is basically related with the hydrothermal process following the volcanic activity of the Goderdzi suite [4]; the solutions fluently circulated through highly porous volcanogenic rocks and brought large amount of silica (SiO_2) into the wood channels. It was established that the petrification of wood developed stage by stage: at the initial stage there was formed quartz, at the intermediate stage – fibrous quartz and chalcedony, while at the final stage, due to low temperature, the process was hampered and microcrystalline α-cristobalite and α-tridymite were segregated though, as the authors assume, partially the opaline tridymite and cristobalite were formed as well.

Besides the polarizing microscope, X-ray diffraction and X-ray fluorescence analyzers were used to define the wood structure and the essence, size, forms, composition, inclusions and joints of the phases crystallized in it.

On the surface of the petrified wood sample (3-Go) the annual light and dark parallel stripes of wood growth are visually (macroscopically) indistinct while under the gemological microscope on the horizontal (transversal) surface of the wood there are clearly observed white and dark thinnest, parallel, zigzag-like lines distributed almost orthogonally against the annual stripes of the wood growth.

a


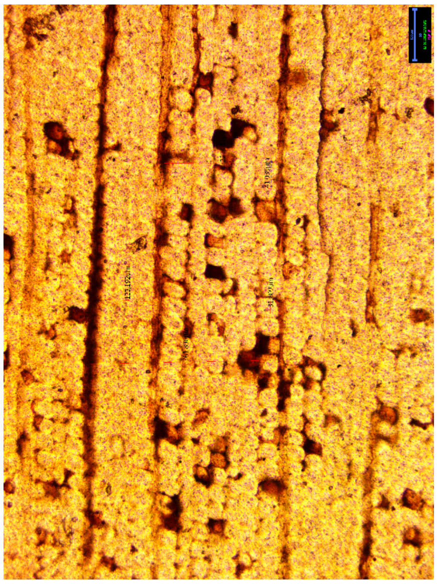
b


Fig. 1. Micrographs (100x) of the plate of horizontal (transverse) section of the petrified wood sample (3-Go) made by polarizing microscope; wavy (a) and horizontal stripes (b).

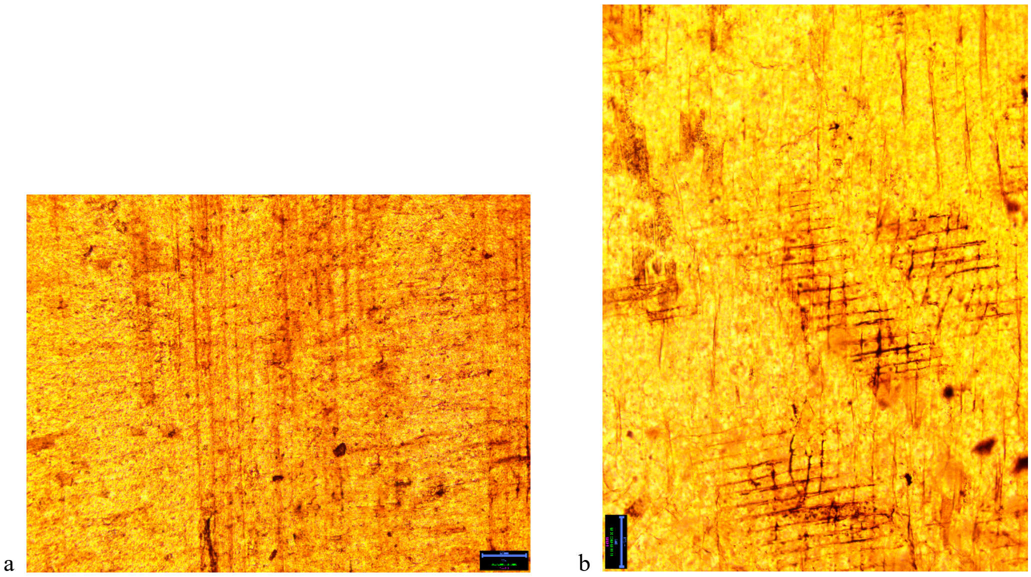


Fig. 2. Micrograph (100x) of the plate of vertical (radial-a and tangential-b) section of the petrified wood sample made by polarizing microscope by one nicol (-), crossed nicols (+).

The polarizing microscopic study of the thin section (Fig. 1) of the plate of horizontal (transversal) section of the petrified wood sample (3-Go) showed that there were clearly observed thinnest lines, often of wavy texture, distributed almost orthogonally to the annual stripes of the wood growth. The tracheids are filled up with fibrous quartz and chalcedony.

Investigations by a polarizing microscope showed that in the thin section (Fig. 2a) of the plate of vertical (radial) section of the petrified wood sample (3-Go) there are seen linear-fibrous channels parallel to the annual stripes of the wood growth; their cellular structure differs from that of the linear-fibrous cells observed on the surface of horizontal section. Vertical cells are often intermingled and transferred into each other; they are almost completely filled with quartz group minerals (quartz of various sizes, chalcedony). Tracheids create quite regular series.

Investigations by a polarizing microscope showed that in the thin section (Fig. 2b) of the plate of vertical (tangential) section of the petrified wood sample (3-Go), there are distinctly seen vertical stripes of the wood – tracheids. The tracheids create quite regular series filled by fibrous quartz crystals and partially by small quantity of α-cristobalite and α-tridymite phases. Sometimes the voids are filled only by chalcedony.

On the surface of the petrified wood sample (27-Go) annual light and dark parallel strips (Fig. 3a) of wood growth are visually distinctly observed while according to the data of the gemological microscope on the horizontal (transverse) surface there are clearly observed white and dark thinnest parallel strips (Fig. 3b) distributed almost orthogonally towards the annual stripes of the wood growth. At the final stage of the wood petrification when the process of crystallization was hampered due to low temperature, the microcrystalline α-cristobalite and α-tridymite and, partially, opaline tridymite were segregated.

Observations by a polarizing microscope show that in the thin section (Fig. 4a) of the plate of horizontal (transversally) section of the petrified wood sample there are distinctly seen light and dark thinnest parallel lines distributed orthogonally towards the annual stripes of the wood growth; they are almost completely filled up with α-cristobalite and α-tridymite microcrystals though there is developed opal-christobalit-tridimite phase as well.

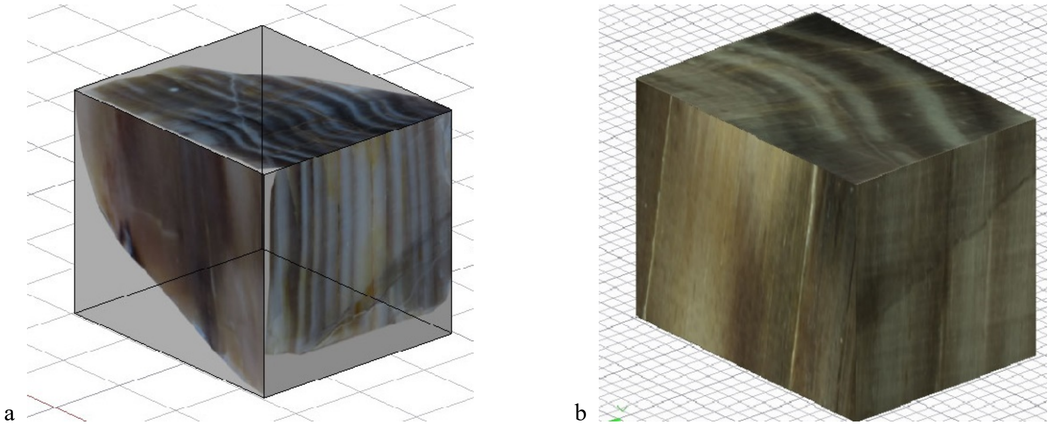


Fig. 3. Photograph of the horizontal (transverse) section of the petrified wood sample 27-Go (a) and that of made by gemological (50x) microscope (b).

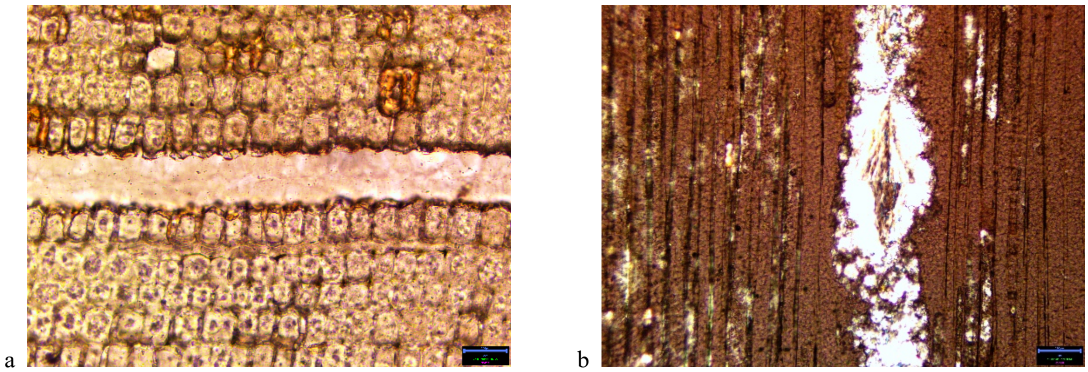


Fig. 4. Micrographs (100x) of the plate of horizontal (traversal) and vertical (radial) section of the petrified wood sample 27-Go made by polarizing microscope by one nicol (-).

Macroscopic observations of vertical (radial) section of the petrified wood sample (27-Go) distinctly showed light and dark thin strips of the wood growth while under the gemological microscope there occur thinnest, parallel lines coinciding them.

Investigations by polarizing microscope show that in the thin section (Fig. 4b) of the plate of vertical (radial) section of the petrified wood sample (27-Go), there is distinctly seen vertical cellular texture with the thinnest strips, parallel to light and dark circles of the wood growth that are almost completely filled up with α-cristobalite and α-tridymite microcrystals; in this structure there also occur fibrous chalcedonies. Tracheids create rather regular series.

The X-ray diffraction patterns distinctly show that wood fibers are replaced by low-temperature microcrystalline α-cristobalite and α-tridymite phases.

The direction of the annual strips of the wood growth developed on the surface of the plate of vertical (tangental) section of the petrified wood sample (27-Go) is almost parallel to that of tracheids.

Observations by a polarizing microscope showed that in the thin section (Fig. 5) of the plate of vertical (tangential) section of the petrified wood sample (27-Go), there is seen a layer of the wood annual growth where original and later tracheids, almost completely filled up with microcrytalline α-cristobalite and α-tridymite phases, are distinguished.

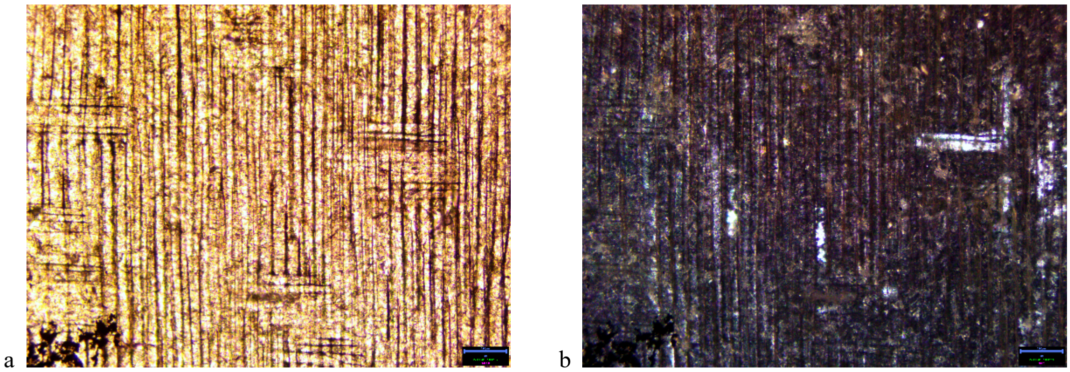


Fig. 5. Micrographs (200x) of the plate of vertical (tangential) section of the petrified wood sample 27-Go made by polarizing microscope: by one nicol(-), by cross nicols(+).

In some petrified wood samples together with fibrous quartz, chalcedony, α-cristobalite and α-tridymite the interlayers of fine-grained sulfide mineral segregations are developed along the stripes of growth.

According to the results of the conducted integrated field and laboratory studies the process of crystallization of thermal springs, causing petrification of trees in the Goderdzi Petrified Forest developed in stages; the process of silicification is related with the hydrothermal solutions following the volcanic activity of the Goderdzi suite; these solutions circulated fluently through pores of volcanogenic rocks and brought large amount of silica in the channels of linear-fibrous cells of petrified wood. Depending upon the thermodynamic conditions and the concentration of solutions of different types of quarts (SiO_2) were simultaneously formed. In the Goderdzi suite the wood petrification developed in stages; at the initial stage holocrystalline quartz was formed, at the intermediate stage – fibrous quartz and chalcedony and at the final stage of crystallization under the low-temperature conditions when the process of crystallization of thermal springs was hampered the low-temperature microcrystalline α-cristobalite and α-tridymite were segregated. Disordered varieties of partially opaline opal-tridymite, opal-cristobalite or opal-crystobalite-tridymite were formed as well. Due to the diversities of minerals formed during the process of silicification (the process of crystallization) of the petrified wood (silicification) took place within 250-130^{o}C temperature interval.

Polarizing microscopic investigation of the thin sections of wood showed that the cellular texture of thin-walled and thick-walled fibers (tracheids) in the petrified wood is linear-fibrous and the original organic material is almost completely replaced by quartz group minerals in such a way that the original texture of the wood is almost undestroyed.

გეოლოგია

ახალი მონაცემები გოდერძის გაქვავებული ხის ფორმირების შესახებ (საქართველო)

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(წარმოდგენილია აკადემიის წევრის დ. შენგელიას მიერ)

გოდერძის ნამარხი ტყის გაქვავებული ხეების წარმოქმნა ვულკანიზმის აქტივობის მომყოლი დაბალტემპერატურული ჰიდროთერმული ხსნარების კრისტალიზაციის შედეგია. კაჟმიწით გამდიდრებული ჰიდროთერმული ხსნარები თავისუფლად ცირკულირებდა განამარხებული ხეების მერქნის ხაზობრივ-ბოჭკოვანი უჯრედების არხებში, სადაც გაკვარცების პროცესი რამდენიმე ეტაპად მიმდინარეობდა. გაქვავებული ხის ნიმუშების ჰორიზონტალური (განივი) კვეთის ფირფიტის ზედაპირზე ვიზუალურად (მაკროსკოპულად) თვალნათლივ დაიკვირვება მერქნის ზრდის წლიური ღია და მუქი პარალელური ზოლები, ხოლო გემოლოგიური და პოლარიზაციული მიკროსკოპით მერქნის ზრდის წლიურ ღია და მუქ პარალელურ ზოლებთან ერთად ჩანს მათი თითქმის მართობული მიმართულებით განვითარებული უწვრილესი თეთრი და მუქი პარალელური ხაზები. მერქნის ხაზობრივ-ბოჭკოვანი უჯრედების არხები მთლიანადაა ამოვსებული სხვადასხვა ტემპერატურაზე გამოკრისტალებული კვარცის ჯგუფის მინერალებით. გაქვავებული ხის ნიმუშების ვერტიკალური (რადიალური და ტანგენტალური) კვეთის ფირფიტის ზედაპირზე მაკროსკოპულად თვალსაჩინოა მერქნის ზრდის წვრილი კანონზომიერი ღია და მუქი ზოლები, ხოლო გემოლოგიური და პოლარიზაციული მიკროსკოპით – მათი თანხვედრილი უწვრილესი პარალელური ხაზები. გაქვავებული ხეების გაკვარცების საწყის ეტაპზე წარმოიქმნება სრულკრისტალური კვარცი, შუალედურ ეტაპზე ბოჭკოსებრი კვარცი და ქალცედონი, ხოლო კრისტალიზაციის ბოლო სტადიაზე – დაბალტემპერატურული მიკროკრისტალური α-კრისტობალიტი და α-ტრიდიმიტი. გაკვარცების პროცესში გამოყოფილი მინერალების სახეობებიდან გამომდინარე, გაქვავებული ხის კრისტალიზაციის პროცესი მიმდინარეობდა 250-130^{0}C ტემპერატურის ინტერვალში.

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