Origin and formation qualification of Khur o Biabanak agates, Isfahan province

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Introduction
Agates are presumed as a kind of precious stone that could be formed in magmatic, metamorphic and even sedimentary environment. Mechanism for agate formation is not clear and is produced in laboratories. Some hot springs and geothermal activity or white chimneys in the ocean floor, have some deposits like chalcedony but never produce agate. Agate formation temperature varies between 50 and 400 °C (Hopkinson et al., 1998).

Materials and Methods
Following field studies, 6 unaltered samples from the parent rock and silicic zone were collected. Analytical data were obtained by X-Ray Fluorescence (XRF) for major elements and Inductively Coupled Plasma Mass Spectrometry (ICP-MS) for selected trace elements at the School of Earth and Environmental Science, Washington State University (WSU), USA. The stable isotope analysis was performed at the Department of Ecology and Evolutionary Biology, Oregon University, USA. Silica samples mineralogy was determined by X-Ray Diffraction (XRD), using Rigaku Ultimate III advance powder equipped; operating at 50 kV and 50 mA, using a Ni filtered Cu Kα radiation.

Results
Tashtab Mountain is a part of the Central Iranian micro-continent which belongs to Cenozoic. The study area is located in northeastern Isfahan province and is in the Yazd block surrounded by three major faults as a graben, consisting of Doruneh fault in the north, Torkmani-Ordib in the south, and Posht-e-Badam fault on the right side. The study area is dominated by Eocene volcanic rocks ranging from alkali basalt, trachybasalt, trachy-andesite to trachyte with minor subvolcanic and plutonic rocks. The Darreh Anjir conglomerate at the base and the Qom Formation at the top, consisting mostly of sandstone and limestone, enclosed the Eocene volcanics. Khur bentonite horizon forms as a result of alteration of these volcanic rocks.

In an overall field observation, the volcanic parent rock appears as short hills surrounded by bentonite deposits, which formed as a result of alteration of volcanic rocks. Outcrops of silicic compositions have been developed as agates, geodes, jasperoids, and siliceous veins. The volcanic rocks are plotted on the discrimination diagrams proposed by (Winchester and Floyd, 1977). The projection of the volcanic samples on the Nb/Y against Zr/TiO₂ diagram shows the composition from andesite to andesite basalt.

The XRD analysis revealed that assemblage of these silicic rocks composed of quartz, calcite, dolomite and hematite. These silica compounds have been mostly formed near the faults and fine joints, also some agates can show the growth during fault activities. Formation of calcite adjacent to quartz in a geode, with a serrate margin is something unusual. Silica and calcite could not be formed in the same pH condition; therefore, it seems that silicic hydrothermal fluids flow outward alternatively in an alkaline aqueous basin. Calcite macles show a temperature of below 200°C in (Burkhard, 1993). Rare earth elements in the silicic samples show a similar trend with host rock. A strong removal of all elements has occurred. HREEs removal happens more than LREEs. The relation between REEs in the silicic samples and host rock happens as a result of fluid circulation inside the host rock.

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during and after alteration. Strontium and Zr depletion represents less than other elements. Strontium can replace the calcium carbonate compounds. Uranium is not changed and has the same amount of silica and host rock. High concentrations of some elements such as Ge, U, and B especially in agates indicate that hydrothermal fluids can play a role in the alteration of volcanic rocks, the mobilization and transport of SiO₂. Cesium is enriched in the silicic samples and is one of the products of U decay. Concentration of Cs and formation of violet agates could happen due to the weak effect of radioactive elements in the region.

Two silicic samples from agate and silicic vein were selected for oxygen-deuterium stable isotopic analysis. The isotopic distribution of mineral-fluid is affected by temperature changes. A variety of methods for determining the oxygen isotope distribution coefficient between quartz and fluid at different temperatures are presented. The Clayton et al. (Clayton et al., 1972) equation was used to calculate the oxygen distribution coefficient between water and quartz.

\[ 10^3 \ln \alpha_{(Qz-H2O)} = \frac{(3.38 \times 10^{10})}{T^2} - 2.9 \]

Due to the lack of water in quartz structure, all deuterium could be estimated as hydrothermal fluids deuterium. Therefore, no correction is needed. Study of oxygen and deuterium stable isotopes in two samples of silica and comparing the results with normal reservoirs of silica samples, determines the type of atmospheric water. Analysis of two silicic samples and comparison with some natural reservoirs suggests that hydrothermal fluids has atmospheric source.

**Discussion**

The Khur agates formed in the cavities of Eocene volcanics with andesitic basalt composition within the Khur bentonite horizon. Field observation indicates that the Khur agates formed independent of faults and joints. According to the XRD analysis, their composition mainly consists of silica and calcite, as well as dolomite and barite in lower quantities. Trace elements and REEs in both silicic samples and andesitic host rock has same trend with large amount of depletion in the silicic samples. Mineralogical evidence suggests that Tashtab agates formed as a result of periodic eruption of low temperature hydrothermal fluids. Also, oxygen and deuterium stable isotope data resemble hydrothermal fluids with atmospheric origin.

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**References**


