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Natural zeolite formation in Mongolia
(volcanogenic-sedimentary zeolite)

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ABSTRACT

The genesis of natural zeolite in Mongolia is attributable to the late Mesozoic tectonic-magmatism activity in East Mongolia - Dornod. The numerous volcanoes formed during this activation process were surrounded by Cretaceous depressions with mineralized waters (Na^+, K^+, Ca^+, Mg^+, Al^+, H^+, SO_4^{2-}, CO_3^{2-}, Cl^-, O^{2-} etc.). The huge amount of ash (glass) emanating from volcanic eruptions fell into the mineralized waters; the hydrolysis of amorphous (silicon-oxygen) structure of the glassy ash was dispersed by the effects of acid and alkaline in the water and became colloids. With the water composition transformation, the silicon and oxygen ions bonded together to form tetrahedral radicals, so forming a structure built up through low-pressure silicon-oxygen chains to become the spongy, web-like structural "skeletons" of zeolite minerals. This silicon-oxygen net structure has hollow spaces of varying sizes, which generates strong charges inside, capable of pulling in and out ions and molecules of various dimensions. These naturally occurred rocks (zeolite) are referred to as "molecular sieves" functioning as a sort of colander for radicals. In other words, it breathes. By this means, a vast region developed rich in natural zeolites of many different types under the influence of the geological, paleogeographic and crystallographic factors noted above and have the volcanic sediments' origin. Among these, clinoptilolite, chabazite and mordenite deposits have, according to our research, a strategic significance for our country's possible chemical pollution and nuclear poisoning (reflected in the next article). Also, it is now very obvious that Mongolia's natural zeolites can be used in many branches like heavy industries, construction, agriculture, livestock and household needs.

Keywords: Zeolite, Genesis, Mongolia

INTRODUCTION

Studies on natural zeolites intensified since the end of the 1970s with the commencement of zeolites being used worldwide in industrial and agricultural sectors due to the special properties of zeolites in adsorption and ion exchange. In 1984, Mongolian and Russian Academy of Sciences jointly organized two expedition teams consisting of B.Tumenbayar, V.V.Petrova, D.Badamgarav and A.G.Kossovskaya to find zeolites of such properties in Mongolia. Over a period of four years the teams discovered 23

occurrences and 4 deposits of zeolites here in Mongolia (Zaitsev et al., 1986; Petrova et al., 1987; Petrova and Amarjargal, 1996; Tumenbayar et al., 1986, 1990). Soon afterwards the Ministry of Geology conducted a resource evaluation of the four zeolite deposits (Ivaanjav et al., 1989) as recommended (Zaitsev et al., 1985; Sokolova et al., 1988). Also, many other prominent scholars and geologists, J.Badamgarav, L.Munkhtogoo, T.Binderiya, P.Shaandar, G.Bumburuu, Ts.Lodoi, N.Tsengelbayar, N.Munkhbat, Z.Dashdavaa, P.Amarjargal, V.F.Shuvalov, Yu.B.Mironov, A.L.Sokolova, V.N.Semushin, N.N.Verzilin, I.A.Belitsskii, R.Grayson and C.L.Johnson, have studied and discovered about 30 new occurrences of natural zeolites in Mongolia.

RESULT

Today there are 42 types of zeolite minerals known in nature. In Mongolia have been discovered over 50 deposits and occurrences of clinoptilolite, mordenite, heulandite, chabazite, ferrierite, eronite, analcime, laumontite and stilbite. Mongolia's zeolite deposits are found mainly in three geographical zones (Fig. 1).

The formation of more than 90 percent of zeolite deposits in Tsagaantsav sediment can be traced back to the Mesozoic tectonic-magmatism activation in the Mesozoic Rift

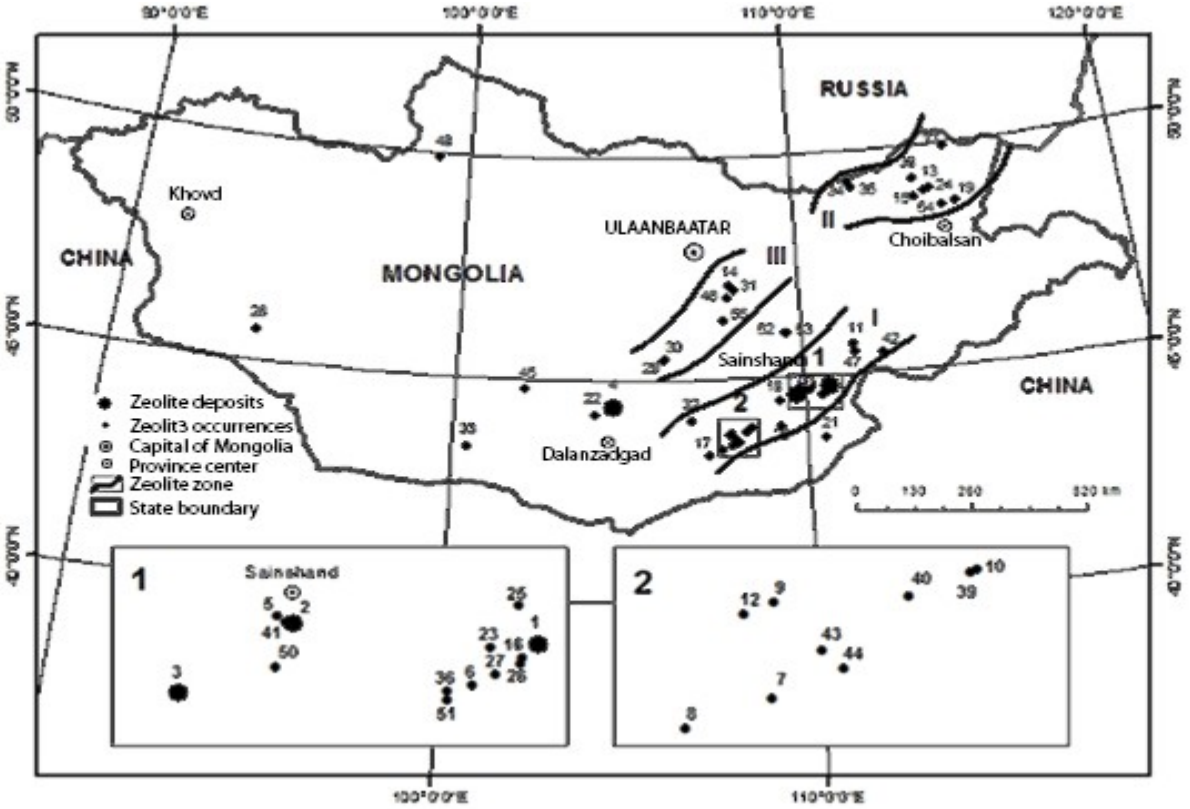

Fig. 1. Distribution of zeolite deposits in Mongolia

I. Zuunbayan zeolite zone: 1-Urgun; 2-Tushleg (3); 3-Tsagaantsav; 5-Tushleg (X); 6-Aman us; 7-Amtgai 1; 8-Amtgai 2; 9-Argalant; 10-Bayan-Ovoo; 11-Bayanmunkh; 12-Bumba; 16-Khailaastyn am; 17-Khanbogd; 18-Khar khutul; 20-Dulaan khar; 23-Urgun (X); 25-Khongil tsav; 26-Khongor morit 1; 27-Khongor morit 2; 32-Manlai; 36-Sugdukh; 39-Tsagaan suvarga (3); 40-Tsagaan suvarga (B); 41-Tushleg (B); 42-Ukhaa tolgoi; 43-Ulgii (X); 44-Ulgii (U); 47-Nergui 2; 50-Nergui 23; 51-Uzuur khar.

II. Dornod zeolite zone: 13-Bumbat; 15-Ikh zos lake; 19-Ulaan shiree; 24-Kholtos; 34-Ilrel 119; 35-Ilrel 153; 37-Suuj; 38-Takhilgat; 54-Yakhiin lake.

III. Other zeolites: 4-Durvun dert; 14-Elgen bulag; 21-Khavkhlant mountain; 22-Khetsuu teeg; 28-Laumontite; 29-Golden mountain 1; 30-Golden mountain 2; 31-Magnai; 33-Naranbulag; 45-Ulzii; 46-Nergui 1; 48-Nergui 8; 52-XX-1; 53-XX-2; 55-Zamyn ulaan.

Zone of East-Mongolia (Zaitsev et al., 1986; Tumenbayar et al., 1990; Petrova and Amarjargal, 1996).

The Tsagaantsav Formation consists of two distinct sections, lower and upper. The lower section consists of volcanic rocks (basalt, rhyolite and trachyte); while the upper section consists of volcanic-sedimentary ash (tuff) and sediments (clays, gravels and sands) (Tsogtbaatar and Ichinorov, 2019). The tuff section contains an abundance of natural zeolite (Luvsandanzan and Tumenbayar 1985; Shuvalov et al., 1987).

DISCUSSION

In order to generate natural zeolites, combinations of three sets of conditions are essential: geological, paleogeographical and crystallochemical. In Mongolia the three essential conditions are fulfilled:

Geological conditions: abundant spreads of weak acidic or alkali rocks, especially volcanic ashes, are present in the areas where volcanoes erupted.

Paleogeographical conditions: These volcanoes must have been surrounded with saline (Na^+, K^+, Ca^+, Mg^+, Al^+, H^+, SO_4^{2-}, CO_3^{2-}, Cl^-, O^{2-} etc.) lakes and ponds during late Cretaceous times (Tumenbayar et al., 1987; Shuvalov et al., 1987).

These conditions are both satisfied very widely in Eastern Mongolia (see Fig. 2). As an example, the zeolite zone in Zuunbayan is presented below (Figs. 3 and 4). The general appearance of a zeolite deposit is shown below (Figs. 5 and 6).

Crystallochemical conditions: The huge amount of ash (glass) emanating from volcanoes' eruptions fell into mineralized water; and the amorphous (silicon-oxygen) glassy structure was dispersed by the acidic and alkaline effects in the water and rendered colloidal. In the process of water composition transformation (pH, eH), silicon and oxygen ions bonded together to form tetrahedral radicals, which further forming a structure built up through low-pressure silicon oxygen chain, a spongy, web like constructed "skeleton" of zeolite. This

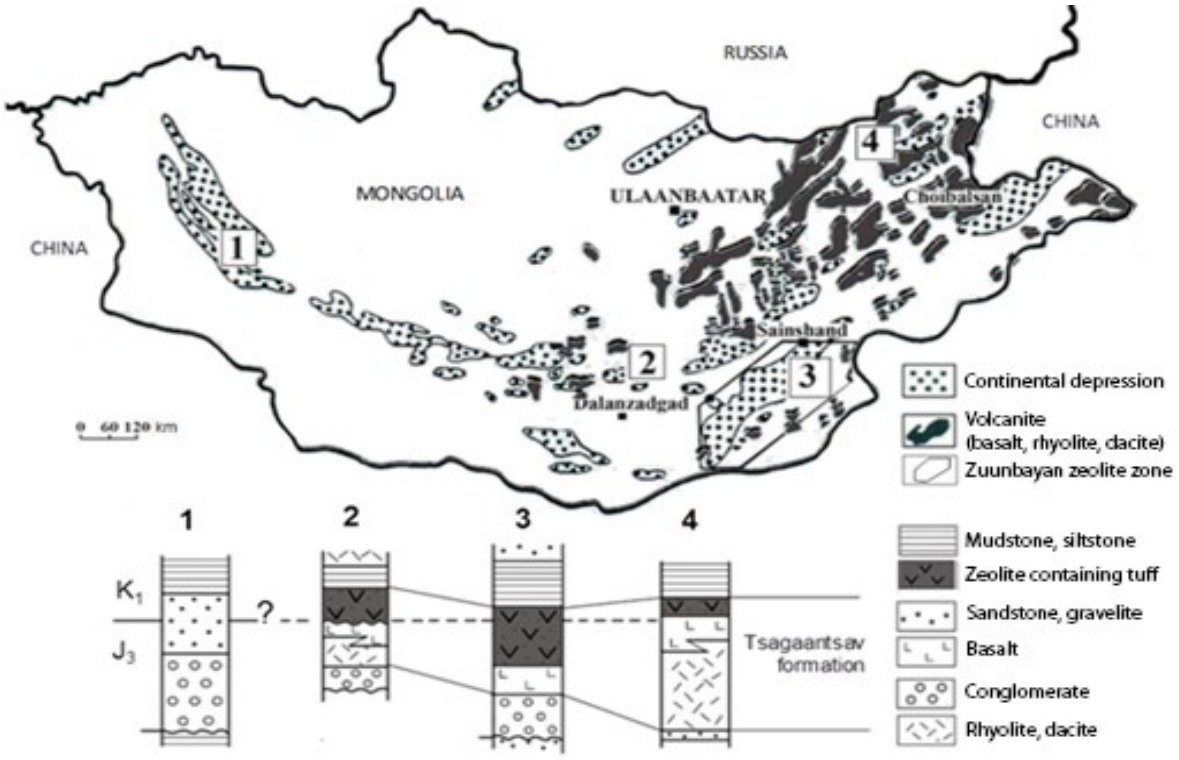

Fig. 2. Geological and paleogeographical conditions to form natural zeolite in Mongolia

silicon-oxygen net-structure has hollow spaces of varying sizes, which generates strong charges inside are capable to pull in and out ions and molecules of various dimensions. These naturally occurring rocks (zeolites) are referred to as "molecular sieves" functioning as a sort of colander for radicals. In other words the zeolite structure breathes in and out.

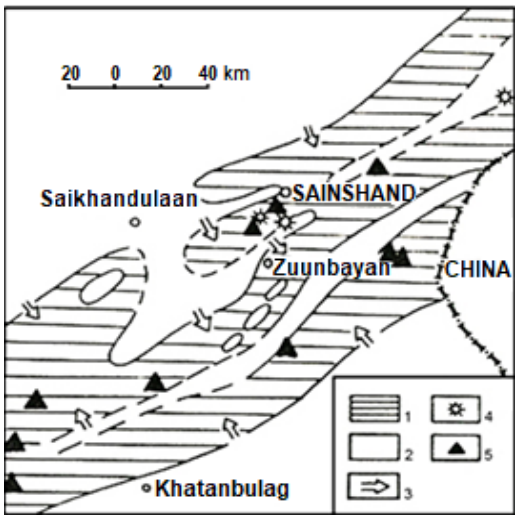

Fig. 3. Paleogeography of Zuunbayan basin (figure modified after Shuvalov et al., 1982)
1-Salty water depression (sediments).
2-Uplifted area.
3-Erosion trend.
4-Volcanoes.
5-Natural zeolite deposits.

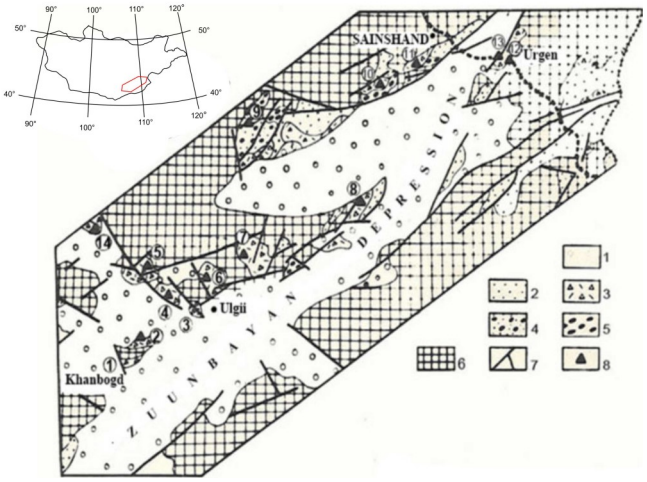

Fig. 4. Zuunbayan depression geology and zeolites
1-Upper Cretaceous-Cenozoic sediments. 2-Lower Cretaceous conglomerates, sandstone and aleurolite. 3-Upper Jurassic - Lower Cretaceous (Tsagaantsav) zeolite -bearing tuff, 4-Upper Jurassic conglomerates and clay, 5-Lower-Mid Jurassic conglomerate, gravellite, shale & coal. 6-Pre-Mesozoic basins; 7-fault, 8-Natural zeolite deposits: (1-Khanbogd, 2-Amtgai, 3-Ulgii, 4-North Ulgii, 5-Argalant, 6-Tsagaan suvarga, 7-Bayan-Ovoo, 8-Dulaan khar ovoo, 9-Khar khutul, 10-Tsagaantsav, 11-Tushleg, 12-Urgun, 13-Manlai). 9-Tsagaantsav and Tushleg region.

Fig. 5. General appearance of the Tsagaantsav zeolite deposit

Fig. 6. First drilling of the Tsagaantsav zeolite deposit. Geologists D.Ivaanjav and B.Tumenbayar 1985

CONCLUSION

So, in Mongolia emerged a vast zeolite region containing many different types of zeolites displaying a wide range of adsorption and ion-exchange properties, under the influence of favourable geological, paleogeographic and crystallographic factors outlined above. All originated from tuffaceous volcanic sediments deposited in lakes and ponds. Among these, clinoptilolite, chabazite and mordenite deposits have, as shown by our research, a strategic significance for our country's possible chemical pollution and nuclear poisoning (Dyer et al. 2006; Tumenbayar and Grayson, 2019).

It is now abundantly evident that Mongolia's natural zeolites have major potential markets in heavy industries, construction, agriculture and livestock feedstuff, including our domestic markets.

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