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New occurrence of albitite from Nubra valley, Ladakh: characterization from mineralogy and whole rock geochemistry

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We report here the occurrence of albitite in Nubra valley of Ladakh region in the Trans-Himalaya area within Indian Territory at 34°44′46″N and 77°33′8″E before Panamik (in the Wish Pond, local name of the area). The albitite has been characterized by petrography, mineral chemistry, X-ray diffraction and whole rock geochemistry (i.e. major, trace and rare earth elements (REE)). The albitite comprises 85–96% albite and amphibole, whereas apatite, zircon and ilmenite occur as accessory minerals. The textural relationship and geochemical data indicate its igneous origin. The albitite contains about 5–6 ppm U and Th which may possibly host U-REE mineralization.

Keywords: Albitite, Karakoram, mineral chemistry, XRD, whole rock chemistry.

A number of albitite occurrences have been described in India within the Archaean basement and the Meso-Proterozoic cover rocks of Delhi Supergroup in north-central and northern Rajasthan[1–3]. Till now, there is only one known occurrence of albitite from Himalayan terrain, i.e. Swat valley of Pakistan in association with Mingora ophiolitic mélange[4]. However, such a rock type was not reported from Indian Himalayan or Trans-Himalayan region. Here, we present a detailed account of new occurrence of albitite from the Nubra valley of Shyok Suture Zone (SSZ) in trans-Himalayan region, based on petrography, XRD, mineral chemistry and whole rock geochemistry. The significance of albitite in Trans-Himalaya is important due to its peculiar occurrence in subduction-related tectonic setting (i.e. Shyok Suture Zone), whereas the albitites generally occur along the intercontinental rift zone[1–3].

The SSZ is characterized as structural boundary which separates Ladakh magmatic arc in the south from the Karakoram terrain in the north. The SSZ runs parallel to Shyok river[5] (Figure 1). The Karakoram terrain contains a suite of rocks covering mélanges, ophiolites, sedimentary and metamorphic rocks. These rock sequences crop out in the Karakoram Range: the Nubra Formation[6], the Karakoram leucogranite batholith (the Baltoro Plutonic Unit

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in Pakistan), and an older I-type granitoid belt[5]. This granitoid belt runs parallel to Karakoram thrust. The area between Khalsar and Panamik mainly comprises varied lithologies including volcano-sedimentary sequences along with granites (Figure 1). These volcano-sedimentary sequences belong to the Nubra Formation. The Nubra Formation is a rock sequence c. 1–2 km wide cropping out along the foot of the Karakoram Range which occurs between the Tirit batholith and Karakoram leucogranite. This formation comprises gabbro, peridotite, serpentinite interbedded with phyllite, slate limestone, and quartzites[6]. However, the occurrence of ultramafic rocks is unknown in this region[7].

During the field work in Nubra valley in 2014, we found the pods of albitite within the metavolcanics (Figures 1 and 2). The host metavolcanics are metamorphosed up to greenschist facies. The metavolcanics consist of amphibole, epidote, albite, calcite, chlorite, quartz and Fe–Ti oxides, clinozoisite and Cr-spinel. The spinels mostly occur as subhedral to euhedral grains disseminated in the matrix of the other minerals. Epidote and clinozoisite are coarser-grained than other phases.

The albitite rock is characterized by petrography, XRD, mineral chemistry, whole rock chemistry (major, trace and rare earth elements (REE)). The albitite is a leucocratic, coarsely crystalline rock, which is hosted by metavolcanics in the Trans Himalaya. The overall texture of the rock is hypidiomorphic granular. The albitite rock mainly comprises albite, and amphibole; apatite, zircon and ilmenite occur as accessory minerals. Albite occupies 85–96 vol% of the albitite and is found as highly fractured coarse crystals (0.1–5 mm) grain size (Figure 3).

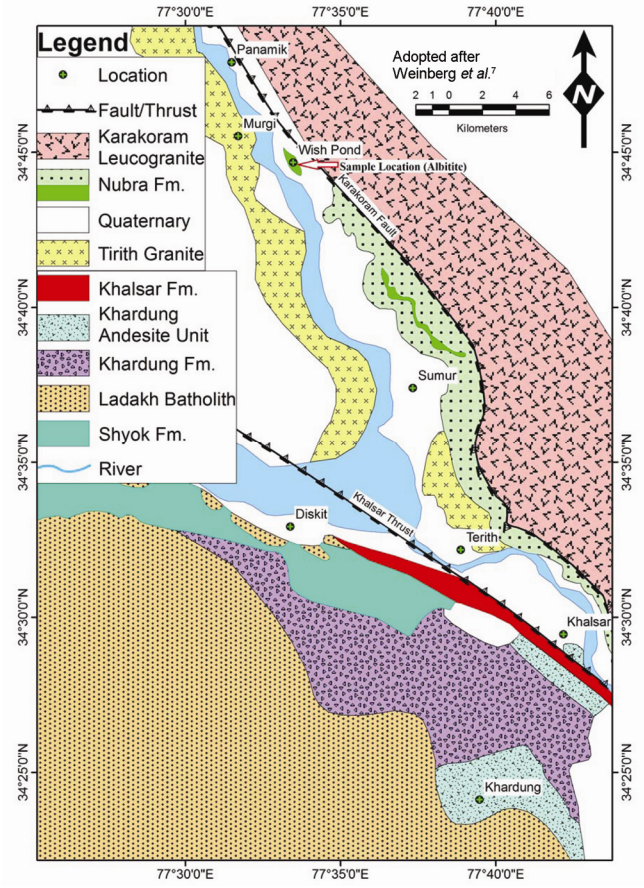

Figure 1. Geological map of the study area, showing the location of the studied sample (modified after Weinberg *et al.*)[7].

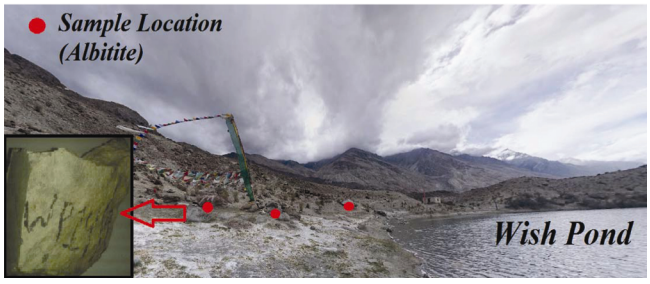

Figure 2. Field photograph of Wish Pond and few sample locations on field.

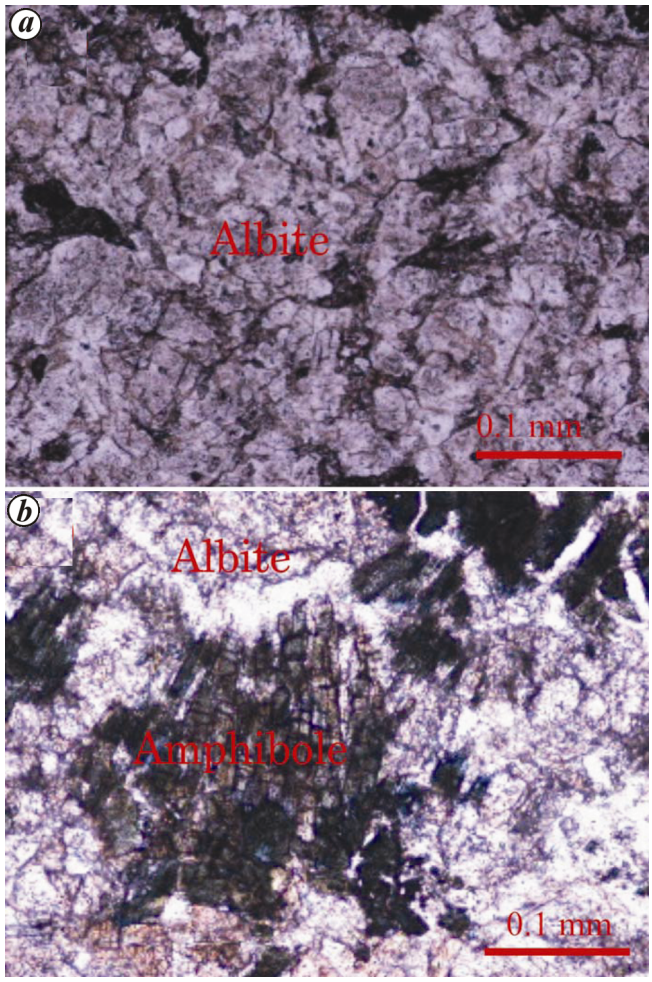

Figure 3. Photomicrograph showing (***a***) plagioclase (albite) grains and (***b***) plagioclase (albite) along with amphibole.

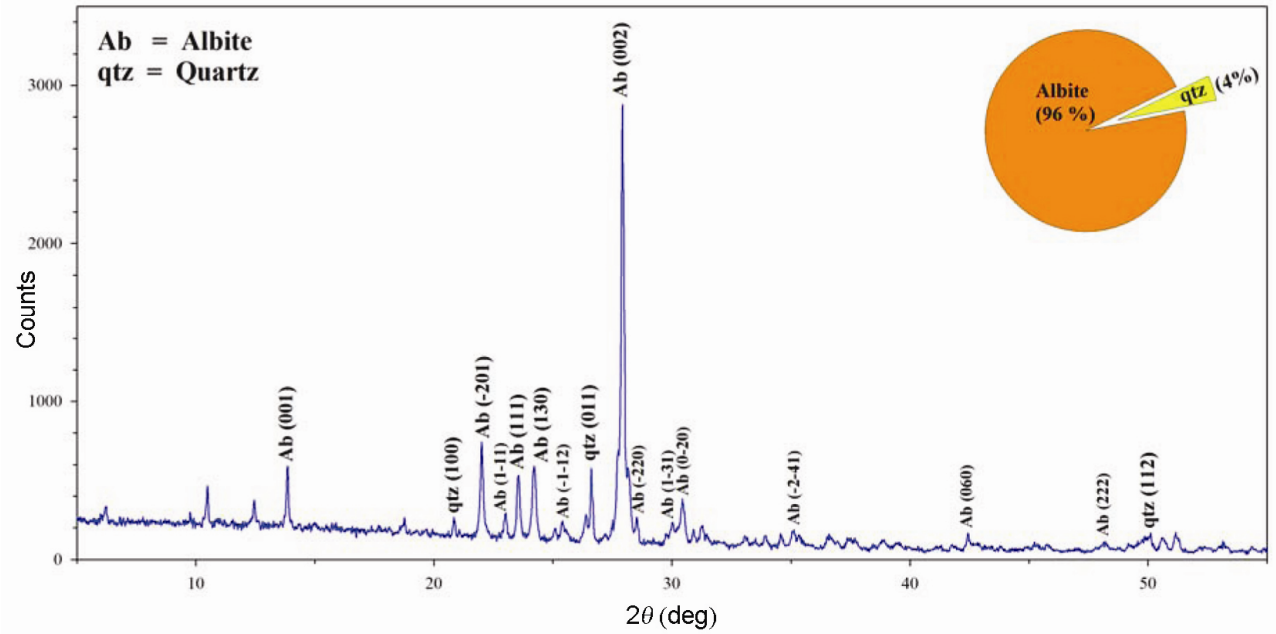

Figure 4. XRD pattern of albitite rock showing predominance of albite.

Table 1. Chemical composition of minerals present in albitite

	Albite		Titianite		Apatite		Amphibole	
SiO_2	67.87	68.34	30.01	30.62	0.02	0.05	53.62	54.12
Al_2O_3	19.97	19.63	0.75	0.80	0.00	0.00	3.96	3.86
Na_2O	11.37	11.67	0.02	0.00	0.00	0.00	1.96	1.89
P_2O_5	0.00	0.00	0.10	0.04	42.74	42.68	0.00	0.00
K_2O	0.09	0.03	0.02	0.01	0.00	0.00	0.13	0.14
CaO	0.79	0.61	28.74	28.89	56.03	56.09	11.64	11.72
TiO_2	0.03	0.00	38.14	37.55	0.03	0.00	0.28	0.23
Cr_2O_3	0.00	0.00	0.08	0.07	0.00	0.00	0.00	0.00
MnO	0.00	0.00	0.01	0.00	0.02	0.00	0.23	0.24
FeO	0.07	0.03	0.36	0.42	0.00	0.00	8.34	8.96
MgO	0.00	0.00	0.00	0.00	0.00	0.00	16.98	17.34
Sum:	100.19	100.31	98.23	98.40	98.84	98.82	97.14	98.76
Cations								
Si	2.966	2.981	3.997	4.066	0.003	0.008	7.632	7.603
Al	1.028	1.009	0.118	0.125	–	–	0.664	0.639
Na	0.963	0.987	0.005	–	–	–	0.225	0.197
P2	–	–	0.011	0.004	6.007	6.001	0.000	0.000
K	0.005	0.002	0.003	0.002	–	–	0.024	0.025
Ca	0.037	0.029	4.102	4.11	9.966	9.981	1.775	1.803
Ti	0.001	–	3.820	3.750	0.004	–	0.030	0.024
Cr	–	–	0.008	0.007	–	–	–	–
Mn	–	–	0.001	–	0.003	–	0.028	0.029
Fe^{2+}	0.002	0.001	0.04	0.047	–	–	0.993	1.053
Mg							3.602	3.631
Or:	0.497	0.157						
Ab:	95.832	97.041						
An:	3.671	2.802						

We carried out the XRD pattern on the sample using the diffractometer system XPERT-PRO at the Wadia Institute of Himalayan Geology (WIHG). The analytical conditions are as follows. The start position (°2Th.) was 2.0004 and end position was (°2Th.) 79.9794. The step size (°2Th.) was 0.0170 and scan step time (s) was

6.0800. The generator settings were 40 mA, 45 kV. The albitic nature of the studied sample was confirmed by XRD (Figure 4).

The mineral chemistry of various minerals in albitite is characterized by EPMA analyses at WIHG. The mineral analyses were obtained using a Cameca SX-100 electron microprobe. The operating conditions were 15 kV and 20 nA with a beam diameter of 1 μm. Natural mineral samples were used for calibration, except that synthetic oxides were used for Mn and Ti. The PAP correction was applied using software provided with the electron microprobe.

The albite ($Ab_{97}An_2Or_1$) occurs as large euhedral to subhedral crystals, archetypally with oscillatory zoning. It displays plastic deformation fabrics such as kink bands and undulatory extinction, and later undergoes brittle fragmentation. Chemical analysis of euhedral plagioclase does not show a large compositional range. The Na contents range from 11.37% to 11.67%. The Ca and Fe vary between 0.61% and 0.79% and 0.3% to 0.7% respectively. This composition can be construed in two ways. First, direct crystallization from Na-rich magma could have occurred[8]. Second, a primary zoned plagioclase could have changed to albite by metasomatism[9].

The albitites contain as much as 3 vol% apatite. Apatite occurs as large subhedral grains, and is commonly highly fractured. Large apatite grains exhibit high concentration of Ca and P content respectively. The Ca varies between 56.01% and 56.07%, whereas P varies from 42.68% to 42.74%. All other elements are present in negligible content (Table 1). Titanite occurs as large anhedral grains. It contains Ca between 28.74% and 28.89%, whereas Ti shows variation between 37.55% and 38.14% (Table 1). Ca-bearing plagioclase is the only source of Ca in titanite, and the titanite is the reaction product of Ca-bearing plagioclase with ilmenite[10]. The representative analyses of amphibole are given in Table 1. Amphiboles are rich in Ca and Mg, which vary between 11.34% to 11.98% and 16.98% to 17.34% respectively. According to the classification of amphiboles by Leake *et al.*[11], the amphiboles are classified as actinolite,

Major and trace elements were analysed at WIHG by WD-XRF (Bruker Tiger S8) following the procedure of Saini *et al.*[12]. REE were analysed using ICP-MS (Perkin Elmer, ELAN DRC-e) following the procedure of Khanna *et al.*[13].

The whole rock analyses of the albitite sample show that these rocks contain large amounts of SiO_2 (63.38 wt%), Al_2O_3 (16.69 wt%), CaO (5.27 wt%), MgO (1.97 wt%) and Na_2O (8.01 wt%) (Table 2). The Sr and Zr concentration in the studied sample is relatively higher (i.e. 324 and 214 ppm respectively) whereas U and Th concentrations vary between 5 and 6 ppm. The albitite sample (HAL) shows similarities in its REE concentration, especially in MREE and HREE with SAL (Slavezines massif albitite)[14], and Central Sadinia, Italy, albitite[15] and Malakwa albitite[16], while LREE (La to Nd) concentration is slightly different from other albitites (Table 2). The studied sample of albitite shows Eu negative anomaly which may relate to original Eu anomalies in the albitite protolith. Similar REE patterns with Eu^- (negative) anomalies were recorded in SAL from France and albitite deposits from central Sardinia (CAL), Italy[14,15]. The

Table 2. Comparative study of major, trace and REE composition of albitite samples

	Ml5	SAL 03-17	CAL	W14A
Oxide (wt%)				
SiO_2	65.00	64.63	68.52	63.38
TiO_2	0.01	0.01	0.18	0.85
Al_2O_3	19.16	20.74	18.70	16.69
Fe_2O_3	0.03	0.34	0.11	0.66
MnO	0.01	0.01	0.01	0.02
MgO	0.02	0.37	0.03	1.97
CaO	0.95	0.90	1.87	5.27
Na_2O	9.70	9.45	10.30	8.01
K_2O	0.06	1.22	0.14	0.24
P_2O_5	0.04	0.20	0.01	0.36
BaO	0.03	1.29	0.24	nd
SrO	0.05	nd	nd	nd
LOI	0.00	nd	nd	1.47
Total	100.06	99.10	100.01	98.92
A/NK (molar)	1.20			
A/CNK (molar)	1.07			
Trace (ppm)				
Cr	8.00	9.26	nd	25.00
Ni	4.00	nd	nd	21.00
Co	2.00	0.21	nd	nd
Zn	1.00	1.57	nd	17.00
Sc	7.00	nd	nd	14.20
Ga	9.00	17.70	nd	17.00
V	7.00	nd	10.00	70.00
Pb	10.00	3.24	nd	16.00
Yb	2.00	0.07	nd	nd
U	0.01	0.52	1.40	5.40
Th	14.00	0.48	57.90	6.00
Hf	1.00	0.04	nd	nd
REE (ppm)				
La	42.00	0.69	82.70	1.949
Ce	70.00	1.83	198.00	5.944
Pr	5.00	0.23	23.00	1.126
Nd	13.00	0.97	87.60	6.545
Sm	2.00	0.23	14.50	2.441
Eu	0.20	0.06	1.10	0.418
Gd	3.00	0.22	6.10	2.331
Tb	0.30	0.03	0.60	0.537
Dy	2.00	0.16	2.70	3.465
Ho	1.00	0.02	0.50	0.773
Er	1.40	0.08	1.40	2.189
Tm	0.23	0.01	0.30	0.318
Yb	1.40	0.07	1.20	1.795
Lu	0.20	0.01	0.30	0.2260

After Boulvais *et al.*[14]; Castorina *et al.*[15]. LOI, Loss of ignition; REE, rare earth elements; nd, no data. MI5, Mlakawa albitite; SAL 03–17, Slavezines massif, France, albitite; CAL, Central Sardinia, Italy, albitite; W14A, Wish pond albitite (studied sample).

A/CNK[A/CNK = $Al_2O_3/(CaO + Na_2O + K_2O)$] ratio of studied sample is 1.20 and A/NK [A/NK = $Al_2O_3/(Na_2O + K_2O)$] ratio is 1.07 which shows close relationship to the peraluminous field according to the criteria of Shand[17] and tends to be Al-saturated with an A/CNK ratio close to 1, which is the value of albite. The SiO_2/Al_2O_3 ratio of studied sample is 3.81. A comparison of this ratio along with A/CNK indicates its relation to trondjemite according to the criteria of Kaur and Mehta[18]. The studied sample from Nubra has $(Na_2O + K_2O)$% concentration of 8.25%. The concentration of $(Na_2O + K_2O)$% versus SiO_2 according to Miyashiro[19] indicates the alkaline nature of the albitite. The alkakine or sodic affinity reveals that the magmatic process leading to formation of albitite was intraplate in nature[20].

The SiO_2, Al_2O_3 and Na_2O contents of the studied sample are very much similar to Rajasthan albitite line[1], whereas Cao content is slightly enriched in comparison to Rajasthan alibitites. It might be possible that Nubra albitite may have some affinity with continental rift environment but the field setting of the studied sample does not corroborate such a tectonic environment.

The geochemical data and textures preserved in the albitite sample indicate that the protolith of Nubra albitite was igneous in origin. Furthermore, the intimate association with ultramafic rocks of the ophiolitic metavolcanics suite suggests a plagiogranite origin for the albitites. The possibility that the Nubra albitite originated from Na-rich magma may be invoked. However, the lack of Na-rich igneous rocks in the ultramafic suite rules out this possibility.

The concentration of uranium in the studied sample is between 5 and 6 ppm. It is a worldwide phenomena that the uranium deposits frequently occurs in soda-rich rocks (i.e. albitite). The significance of this new albitite occurrence in Himalayan terrain may be related to possible uranium–REE mineralization, which may open new vistas for its exploration.

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