THE EARLY CRETACEOUS TSAGAANGOL FORMATION SANDSTONE PROVENANCE AND PALEOCLIMATE

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ABSTRACT

Early Cretaceous Tsagaangol formation refers to Zoolen terrain (G.Badarch., 2002). This study attempts to make classification of the sandstones of the formation, define its sources and identify its alteration and paleoclimate condition. The sandstones of the formation are rich in mineral fragments, especially, quartz (comprising 70-75% of the entire content) and the composition is identified to be varying from subarcose to lithic arcose. As plotted on the source defining diagrams, they have been identified to be of continental block and mixed orogen and to get intensely altered or weathered under warm humid climate condition.

Keywords: Tsagaangol petrography, sandstone, fragments, weathering

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1.Introduction

Tsagaangol formation is located in the area of Bayandalay soum of Umnugovi province, the northern half of the selected area refers to Gobi-Altay zone of the great Altay Mountains region whereas the southern half lies in Altay Inner Gobi zone of the Great Gobi region. In this study we have done petrological studies on total of 14 sandstone samples taken from Lower Cretaceous Tsagaan gol formation (Shuvalov 1982). The studies aim to make classification of the sandstones, identify the source areas, weathering as well as the paleoclimate condition. For the purpose we have applied several different methods as follows: Folk classification diagram (Folk, 1968) Gazzi-Dickinson technique (Gazzi-Dickinson, 1985) and a weathering and paleoclimate implication method (Nesbitt et al, 1996 Rieu et al., 2007).

2. Geology

The survey area is characterized by Middle Ordovician- Llandovery Huzuuvch uul (O_2-S_1 hu), Silurian -Lower Devonian Tumurt (S-D_1tm), Lower Carboniferous Dengiin uul (C_1dn), Lower Middle Jurassic Zuramtay (J_{1-2}zr), Lower Cretaceous Tsagaan aarag (K_1ca), Upper Cretaceous Baruungoyot (K_2bg), Oligocene Shand gol (E_3sg) formations. Huzuuvch uul succession consists of dark grey, brownish grey, greenish grey siltstone, sandstone, silicified siltstone. Tumurt formation is made up of greenish, brownish green, purplish red siltstone, mudstone, green grey and grey sandstone, tuff sandstone and siltstone while Dengiin nuruu formation consists of brownish grey basalt, tuff-sandstone and tuff gravels. Zuramtay formation is composed of coaly mudstone, siltstone, aleurosandstone, grey and pale sandstone, siltstone, and green and multi-colored conglomerate whereas Tsagaan aarag formation consists of brownish grey coaly mudstone, dark grey siltstone, paper schist, rarely sandstone with coal seams and gravels. Baruun goyot formation is characterized by vivid red interbeds of mudstone and siltstone, whitish grey and red sandstone, marl, calcareous marl concretions, gravels, conglobreccia and basal conglomerate. Shand gol formation is made up of dark reddish sands, mudstone, brownish grey and white sandstone interbedded with marl.

Tsagaangol formation, the target area for the studies, was initially identified by B.V. Shuvalov (1982) and named after the adjacently lying wadi called Tsagaan gol which occupies a valley back of the Zuramtay Mountain. The formation which was referred to Lower Cretaceous (Neocom) as for geologic age, is characterized by grey sandstone rich in fauna remnants, mudstone, siltstone and clay covering an extensive area of Zuramtain nuruu, Tsagaan arag khudag and Borzongin gobi of Khurmen soum of Southgobi province.

The formation is subdivided into conformably lying three members. The lower member of conglomerate and sandstone is made up of mudstone interbedded with brownish grey, grey and pale sandstones with the total thickness of 218m the middle member of red mudstone consists of red, dark red mudstone. The upper member of grey mudstone is composed of bluish grey and pale mudstone with light-colored marl and paper schist with poorly reserved flora fossils. The latter is identified to be 75m in thickness (Fig. 1). The total thickness of Tsagaangol formation is 733m (Sh.Lkhundev., 2016).

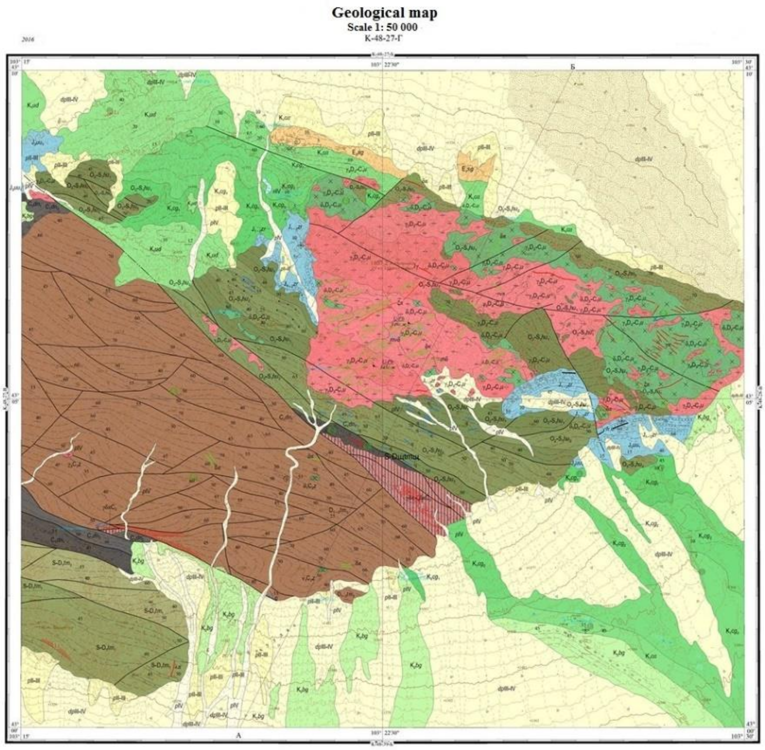

Fig. 1. Geology map of Early Cretaceous Tsagaan gol formation

Tsagaangol formation	K_1cg_3	Grey mudsone member. Bluish grey, pale mudstone with pale paper schist, fossilized woods and poorly preserved flora remnants
	K_1cg_2	Red mudstone member. Green, light grey mudstone, sandstone, siltstone, red and dark red mudstrone
	K_1cg_1	Conglomerate – sandstone member. Mudstone with brownish grey, grey, pale sandstone and conglomerate layers and poorly preserved fish Lycopteia
	$J_{1-2}zr$	Zuramtay formation. Conglomerate, sandstone, coaly mudstone, coal seams siltstone, aleuvrosandstone, mudstone with flora remnants.

3.Methodology

Total of 14 sandstone samples gathered from Lower Cretaceous Tsagaangol formation were analyzed for the purpose of defining the composition, structure, texture, transportation area, source area, weathering, and paleoclimate condition. The thin sections of rock samples taken during the field work were prepared at the Institute of Mineral Resources (former name) and analyzed under NIKON microscope at NUM lab. Counting of total 300 points at each thin section was performed by using Gazzi Dickinson technique and special software in order to identify mineral clasts, cement, accessories and pore spaces.

The result is shown in the table 1.

Table 1. Point counting results of sandstones

Sample ID	Q-F-L,%			Qp-Lvm-Lsm,%		
	Q	F	L	Qp	Lv	Ls
Tsagaangol						
CG-1	73.11	15.47	11.40	83.56	4.56	11.87
CG-2	82.67	12.42	4.89	95.60	1.01	3.37
CG-3	64.62	30.82	4.55	95.37	4.62	0
CG-4	33.03	6.30	60.66	97.90	2.09	0
CG-5	72.19	16.35	11.44	98.49	1.50	0
CG-7	77.02	20.35	2.62	97.29	0	2.70
CG-8	85.93	12.89	1.171	98.15	1.84	0
CG-9	71.46	25.13	3.40	98.03	1.96	0
CG-10	77.53	21.80	0.66	100	0	0
CG-11	61.09	36.43	2.46	97.90	2.09	0
CG-13	70.97	23.59	5.43	97.84	2.15	0
CG-14	70.97	23.59	5.43	97.84	2.15	0
CG-16	73.30	26.69	0	100	0	0
CG-17	80.47	19.52	0	100	0	0

Comment: Q– quartz, Qp–polycrystal quartz, F–feldspar, Lv–volcanic clasts, Lm– metamorphic clasts, Ls–sedimentary clasts

4. Petrography of Tsagaan gol formation

The sandstone samples (sample IDs: CG1, CG2, CG3, CG4, CG5, CG7, CG8, CG10, CG11, CG13, CG14, CG16, CG17) of Lower Cretaceous Tsagaangol formation were analyzed by petrographic analyses. The sandstones are massive in structure and psammitic in texture. Mineral clasts and rock clasts are predominantly observed. The clasts are moderate to well-rounded as well as well sorted. Quartz and plagioclase and K-feldspar are identified. The quartz (Fig. 2-A, thinsection CG-7) and k-feldspar fragments occasionally exhibit as microcline grid pattern (Fig. 2-A, thinsection CG-7). Plagioclase (Fig. 2-B, thinsection CG-12) fragments intensely suffered to pelite and sericite alteration. The rock fragments occur as follow up structures: intrusive rock fragments –micropegmatite (Fig. 2-C thinsection CG-5), siliceous rocks - cryptogranular, andesite microlitic (Fig. 2-D, thinsection CG-9), pylotaxitic, dacite microfelsitic (Fig. 2-D, thinsection CG-9), microquartz - microgranoblastic (Fig. 2- E, F thinsection CG-2, 4) and aleuritic structures in siltstone. The above mentioned fragments are cemented with much carbonate (Fig. 2-F, thinsection CG-2), sericite and chlorite coats, leucoxene and rarely dark reddish biotite. As well, they are well enriched with red hydrous ferric oxide. Ore minerals, zircon, tourmaline, apatite and a few fluorites are observed as accessory minerals (D.Nansalmaa et al., 2009).

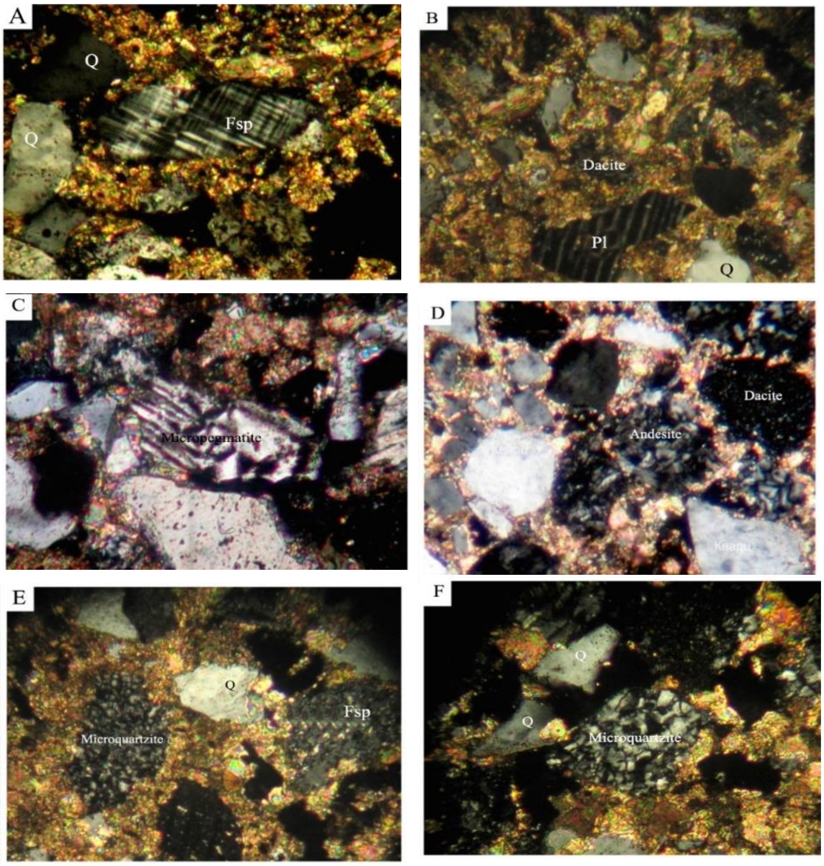

Fig 2*. Lower Cretaceous Tsagaan gol formation sandstone (magnification with analizator 10x) A) Q-Quartz, K sp-K feldspar clasts.. B) Pl-Plagioclase clasts with plagioclase twinnings. C) Intrusive micropegmatitic clasts. D) microlitic andesite and microfelsic dacite clasts. E) microquartzite and K-feldspar clasts Quartz F) microgranoblastic microquartsite clasts, cementing carbonate.*

3.1.1 Sandstone classification

The sandstone classification is illustrated in the Q-F-L diagram (Folk, 1968). The samples taken from Lower Cretaceous Tsagaan gol formation (Fig. 3.) are plotted at arcose, subarcose and lithic arcose areas while only one sample plots at litharenite area.

3.1.2 Qt-F-L diagram

As exhibited in the Qt-F-L diagram, the most of the Lower Cretaceous Tsagaan gol formation sandstones plot on transitional continent and craton interior and just two of them plot on recycled orogen.

3.1.3 Qp-Lvm-Lsm diagram

Qp-Lvm-Lsm diagram shows the counting results of Lower Cretaceous Tsagaan gol formation samples plot on mixed orogenic sand area (Fig.3-C).

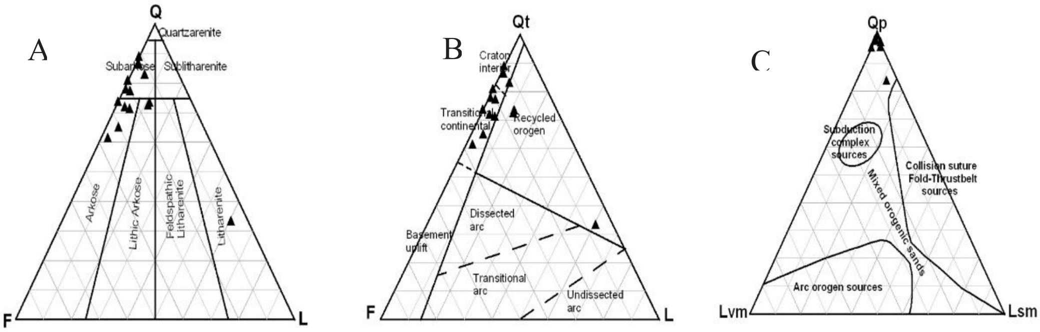

Fig.3. Classification and sources of Lower Cretaceous Tsagaan gol formation
A) Folk sandstone classification diagram (Folk, 1968) B) Qt-F-L diagram C) Qp-Lvm-Lsm diagram – Sandstone source area (Dickinson, 1985)

Source area types of Tsagaan gol formation sandstones are summarized in the table 2.

Table 2. Variety of source areas of Tsagaangol formation sandstone

Age	Qt-F-L	Qp-Lvm-Lsm
Lower Cretaceous (Tsagaangol)	Continental block	Mixed orogeny

Weathering and paleoclimate condition of Tsagaan gol formation sandstones

The weathering level and paleoclimate condition is determined by using MIA(mineralogical index of alteration) or Q-P-K diagram (Nesbitt and Young, 1996). The data used for creating diagram is listed in the table 3. High MIA (mineralogical index of alteration) value range (80-100) indicates warm humid climate condition with intense weathering whereas the value range between 50 and 70 indicates cool condition with less weathering. The point counting results of 14 Tsagaan gol formation sandstone samples plotted on the MIA or Q-P-K (Nesbitt and Young, 1982, Nesbitt 1996) and MIA value for 12 sandstone samples ranges between 73.30 and 88.54 while two samples plot on the weak weathering cool climate condition area because of the value range of 62.64-67.70 (Fig. 4). It shows that Lower Cretaceous Tsagaangol formation sandstones were accumulated under warm humid climate condition and intensely altered

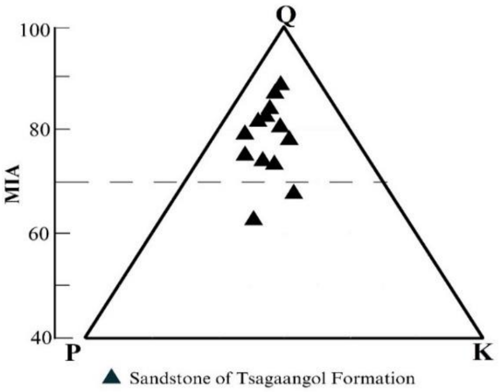

Fig. 4. Sandstone weathering of Tsagaan gol formation (Nesbitt and Young,1996)

Table 3. Lower Cretaceous Tsagaangol formation data results plotted on MIA diagram

№	Qm	Qp	Pot feld	Q	K-feldspar	Pl	MIA	Q	K-feldspar	Pl
CG-1	17.6	18.3	2.6	35.9	2.6	5	82.52874	82.52874	5.977011	11.49425
CG-2	15.6	28.3	2.6	43.9	2.6	4	86.93069	86.93069	5.148515	7.920792
CG-3	16.3	20.6	9.6	36.9	9.6	8	67.70642	67.70642	17.61468	14.6789
CG-4	5	28	2.3	33	2.3	4	83.96947	83.96947	5.852417	10.17812
CG-5	11.3	19.6	2	30.9	2	5	81.53034	81.53034	5.277045	13.19261
CG-7	13.6	21.6	2	35.2	2	7.3	79.10112	79.10112	4.494382	16.40449
CG-8	6	16	1.3	22	1.3	2	86.95652	86.95652	5.13834	7.905138
CG-9	12.3	15	3.6	27.3	3.6	6	73.98374	73.98374	9.756098	16.26016
CG-10	14.6	20.6	5.3	35.2	5.3	4.6	78.04878	78.04878	11.75166	10.19956
CG-11	8.3	14	5	22.3	5	8.3	62.64045	62.64045	14.04494	23.31461
CG-13	10.6	27.3	3.3	37.9	3.3	9.3	75.0495	75.0495	6.534653	18.41584
CG-14	11	40	3	51	3	3.6	88.54167	88.54167	5.208333	6.25
CG-16	9.3	25.3	5.6	34.6	5.6	7	73.30508	73.30508	11.86441	14.83051
CG-17	4.6	15.6	2.3	20.2	2.3	2.6	80.47809	80.47809	9.163347	10.35857

5. Conclusion and Discussion

The results of petrographic analysis of Tsagaangol formation sandstones can be concluded as follows:

- The sandstones vary from subarcose to lithic arcose in composition and are identified to be entirely sourced from continental block.
- Lower Cretaceous Tsagaangol formation sandstones are abundant of quartz fragments and well rounded. It shows the sandstones were intensely altered under warm humid climate condition. The

sandstones which were developed in continental block, craton or along passive continental margins are identified to have more quartz fragments and less rock fragments.

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