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The Characteristics and Genesis of the Massive Nitrate Deposits in the Turpan-Hami Basin of Xinjiang, China

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Massive nitrate deposits have been discovered in the Turpan-Hami basin in northwestern China. Previously, large ore grade nitrate minerals were thought only to exist in the Atacama Desert in northern Chile. Estimates of the amount of nitrate in the Turpan-Hami basin are 250 million metric tones which rival those of the famous Atacama nitrate deposits. The region of the nitrate deposits has a dynamic tectonic history, one that has evolved since the late Permian, transitioning from a wet, humid region into a hyper-arid basin, which may have played a role in the formation of the deposits.

The nitrate deposits which consist of nitratine, halite and mirabilite occur in unconsolidated gritty strata of Pleistocene age of Quaternary. Typical nitrate ore is dense and hard, and the saline minerals occur as fine-grained cements of gritrock and breccia or as disseminated and veined infill in pores and fractures of bedrock. The saline constituents generally have a fine granular texture or porphyritic and nodular structure. The stabilization of the deposits is linked to the aridity of the region that was induced by uplift of the Himalayas.

Two types of nitrate ore are distinguished as either halitic gritrock ore or halitic breccia ore, corresponding to two principal lithologic units of the alluvial fan described as a gritrock unit and a breccia unit. The nitrate ores occur as stratiform seams of 0.3–3.7 meters thick, at depths of 0.2–0.5 m below the gobi surface (Fig. 1). The deposits usually consist of a lower zone (0.4 to 0.7 meters thick) of thenardite that transitions to a upper zone (0.8 to 1.4 meters thick) consisting of halite associated with nitratite and thenardite, which is capped by a 0.4 to 2.0 meter thick zone of nitratite associated with halite and thenardite. This sedimentary positioning is striking, because it is the reverse of saline mineral position in the Atacama, where nitrate ore is usually below chloride that is in turn below sulfate minerals.

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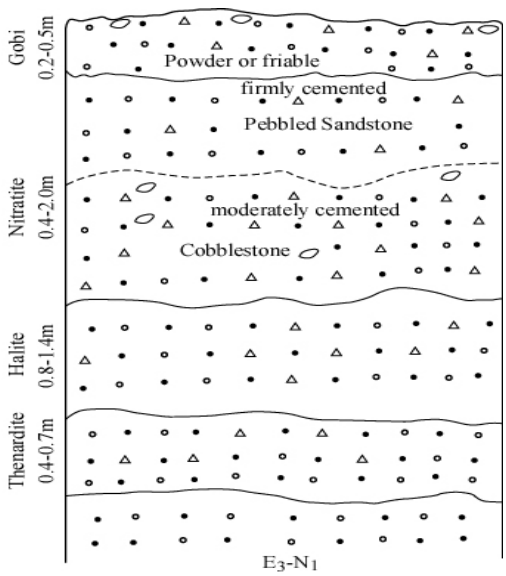

Fig. 1. The profile of the alluvial fan with nitrate deposits.

Based on chemical analyses, the samples of nitrate ore from Kumtag and Danahu nitrate deposit had the average content of ionic saline constituents which are presented in Table 1. These constituents represent the water-soluble material. Because of the great local and regional chemical composition variations, the content of $NaNO_3$ in typical nitrate ore ranges from 2% to 27.98%, with an average of over 10% in detailed exploration zone. The average mineral assemblage of the ore is halite (30%), darapskite (20%), nitratite (10%), thenardite, anhydrite, bassanite and glauberite (3–8%). These are very similar to the mineral

Table 1 The average content of ionic saline constituents in nitrate ore (%)

Deposit	Ca	K	Mg	Na	SO_4^{2-}	Cl^-	NO_3^-	CO_3^{2-}
K[1]	0.311	0.045	0.019	15.96	4.50	18.42	4.82	0.11
D[1]	0.369	0.096	0.008	18.14	6.87	21.27	4.17	0.08
A[2]	1.8	0.7	0.5	6.9	10	4.6	6.3	

K=Kumtag, D=Dananhu, A=Atacama; 1= this study; 2= Ericksen(1983) assemblages found in the Chilean deposits. In addition other oxy-anions of borate, chromate, iodate and bromide, which are known to occur in the natural Chilean deposits, are absent in Turpan-Hami nitrate deposits.

Geochemical and isotopic analyses of the nitrate deposits provide some insights into the origin of the deposits. The nitrates have large ^{17}O isotope anomalies and these capital delta ^{17}O values range from 12 to 18‰. The ^{17}O values observed in the Turpan-Hami nitrates suggest that at least 60–80% of the nitrate is derived from atmospheric deposition of photochemically produced nitrate. Alternatively, the residual 20–40% of the non atmospheric nitrate could be attributed to microbial oxidation of ammonium that may have also been deposited in aerosol form. The hypothesis is supported not only with isotope data but also by perchlorate which has been associated with possible stratospheric processing followed by deposition. The data suggest that in the absence of water, surficial accumulation of photochemical compounds is a major genetic mechanism of massive nitrate deposits.

The existence of massive nitrate deposits in the Turpan-Hami basin, similar to the Atacama, where the deposition of compounds formed by photochemical reactions is one of the dominating pedognic processes has important significances. It suggests that the Atacama is not unique, that the accumulation of inorganic photochemical compounds in hyper-arid regions is a fundamental geologic process. In addition, this may be a biogeochemical feedback mechanism, a way for the Earth system to remove nitrogen by storage and then release a limiting nutrient under different climate regimes.

Key words: Nitrate, photochemical reaction, oxidation of ammonium, Turpan-Hami basin, Xinjiang

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