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Field Geological Exploration of the Ashikule Volcano Group in Western Kunlun Mountains[1]

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From May 4 to May 30, 2011, a field exploration of the Ashikule basin in the Western Kunlun Mountains area was conducted by a research team from the Institute of Geology, China Earthquake Administration and Earthquake Administration of Xinjiang Uygur Autonomous Region. This work is financially supported by the special fund for China earthquake research project "The Comprehensive Scientific Exploration of the M_S7.3 Yutian Earthquake in 2008 and the Ashikule Volcano Group". Through detailed field survey on geological and geomorphological features of the Ashikule volcano group, which is one of the highest altitude volcanic plateaus (about 5000m) in the world, we have determined the total number of volcanoes, the eruption type and structural parameters, and approximate active history of the volcano group. Our studies have provided field evidence for resolving past controversies such as the authenticity of the news report about the eruption event on May 27, 1951, the eruption pattern of the Daheishan volcano, and the reality of the Gaotaishan volcano.

Key words: **Ashikule volcano group**; **Recent eruption**; **Volcano cone**; **Lava**

INTRODUCTION

Ashikule basin is located at the junction of Altyn fault, on western segment of the eastern Kunlun fault, and Kangxiwa fault (Fig. 1a). As a tectonic basin predominated by extensional stress conditions accompanied by shearing, Ashikule basin has undergone intensively neo-tectonic processes due to its special tectonic background. The Ashikule volcano group, which is composed of 10 major volcanoes and tens of sub-volcanoes, covers a total area of about 200km^2 at the average altitude around 5000m, one of the highest volcano groups in the world (Fig. 1b). The

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most volcanoes in the basin formed and developed in the Quaternary period in central vent eruption mode (Deng Wanming, 1989; Liu Jiaqi et al., 1990), so the craters are shaped as typical cones or truncated cones. An explosive eruption was reported to have occurred in the basin on May 27, 1951 by Xinjiang Newspaper, which has been believed to be the most recent volcanic eruption event in the Qinghai-Tibetan plateau (Xinjiang Daily, 1951). However, the reality of such an event has been debated for several decades since no solid evidence, associated with eruptions such as lava, has been found in the field (Deng Wanming, 1989; Li Shuanke, 1991; Liu Jiaqi et al., 1990; Liu Ruoxin et al., 2000). Some reconnaissance field work was carried out to conduct an in situ investigation on the volcano field in the basin in the late 1980's by Qinghai-Tibetan research team members from the Chinese Academy of Sciences. Afterwards, more field work and geological mapping of the Cenozoic volcanic rock in the Ashikule basin was done by the Chinese Academy of Geological Sciences in 2008, when the earthquake emergency expedition was organized to investigate the surface rupture produced by the Yutian M_S7.3 earthquake occurring south of Ashikule basin on March 20, 2008. However, such an uninhabited area with a high altitude, where the Ashikule volcano group is situated, made the basin almost inaccessible for volcanologists to conduct detailed field work in the past. Indeed, the limited previous work only provides some basic understanding of volcanic petrology, geochemistry and brief chronology of volcanism. Some fundamental questions regarding the deep source of magma (where ?), evolution process (how ?) and current state of magma chamber (what ?) are still kept open.

In this paper, we report the most up-to-date results from a one-month field expedition in the Ashikule basin. This work was conducted by the special research team from the Institute of Geology, China Earthquake Administration and Earthquake Administration of Xinjiang Uygur Autonomous Region, which is financially supported by the special fund for the China earthquake research project "The Comprehensive Scientific Exploration of Yutian M_S7.3 Earthquake in 2008 and Ashikule Volcano Group".

1 GEOLOGICAL AND GEOMORPHOLOGICAL FEATURES OF THE ASHIKULE VOLCANO GROUP

The Ashikule volcano group consists of a volcanic series from the late Pliocene epoch (2.8 Ma) to the Holocene, which was classified into 6 volcanic episodes based on the field investigation and K-Ar dating of volcanic rock samples in the previous work (Liu Jiaqi et al., 1990). Some evidence presented by Liu Jiaqi et al. in 1990 supports the possibility of the most recent eruption on May 27, 1951 that was originally reported by Xinjiang Daily (1951). The typical geomorphological features of the volcano group include volcanic cones, lava terraces and lava valleys. Several volcanic chains and clusters in the NE direction are well developed that may be attributed to the regional NE-trending tectonic activity during the eruptions. The main volcanic series of the Ashikule group is lithologically characterized by trachyandesite, trachybasalt and tephrite (Liu Jiaqi, 1999).

1.1 Ashishan Volcano

This volcano, also referred as volcano #1 in the previous work (Zhao Mingyu, 1976), lies on the south of Ashikule basin (Figs. 1b, 2a). Liu Jiaqi et al. considered the Ashishan volcano as the source of the most recent eruption event of 1951 (Liu Jiaqi et al., 1990). The well preserved cone rises 110m above the basin. Inside the cone is an open space of 20m diameter at base and 48m deep. The summit of the cone has a relative higher altitude at the north rim than in south with a height difference of 26m. The outer surface of the cone is relatively smooth and no obvious erosion ditches are observed. A couple of gas vents in diameter about 2m were found

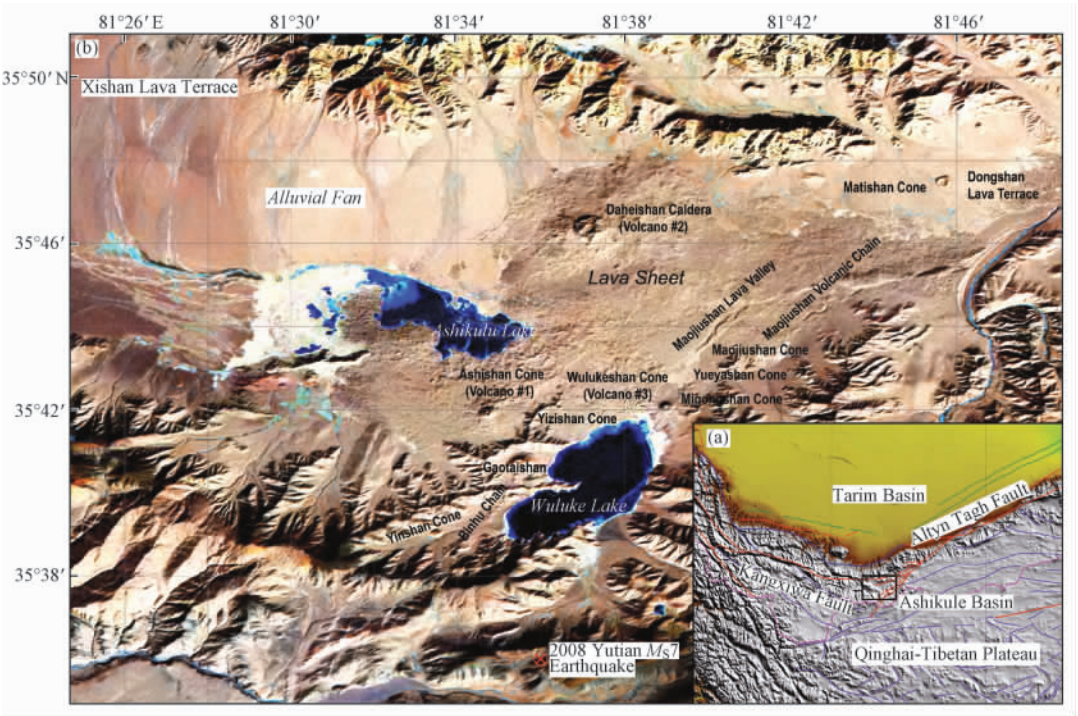

Fig. 1

The tectonic location of Arshikule basin (a) and volcano distribution in the basin (b)

Table 1 Geometric parameters of volcano cones and lava terraces of Ashikule volcano group

Volcano name	Diameter of cone base/length of terrace in the EW direction (m)	Diameter of cone base/length of terrace in the NS direction (m)	Diameter of cone in the EW direction (m)	Diameter of cone in the NS direction (m)
Ashishan	650	530	140	170
Daheishan	1100	1240	510	440
Wulukeshan	680	570	220	210
Yizishan	350	300	150	210
Migongshan	500	490	310	190
Yueyashan	230	210	90	70
Maoniushan	410	310	190	100
Matishan	580	530	360	350
Dongshan lava terrace	3130	3230		
Xishan lava terrace	560	750		

at the north rim of the cone (Fig. 2b) that may be the result of the 1951 eruption. The whole cone is covered with a very thin layer of loess due to the intensive loess activity in this region. Ashishan lava has flowed in all directions from the crater, entering the Ashikule lake in the north and stopped by the foot of the mountain in the south. In the broad distributed lava terrace, lava lakes and splitting ridges can be seen. The structure of the Ashishan volcano cone shows at least three stages during its formation. In the first stage the cinder cone was formed with the mixing of

country rock debris, in black and dark brown color and relatively gentle outer slope. In the second stage, dark brown-cascade deposits were formed around the crater rim by splashdown accumulation, and the inner slope of the cone became steep. Finally, volcanic gas vents were formed in the last stage.

1.2 Daheishan Volcano

This volcano, also referred as volcano #2 in the previous work (Zhao Mingyu, 1976), is located on the north of Ashikule basin (Figs. 1b, 2c). The previous K-Ar dating result suggests that this volcano was formed around 0.5 to 0.6 Ma (Liu Jiaqi et al., 1990). As the largest and highest volcano in the Ashikule basin, with the altitude of summit at 5090m, Daheishan volcano has a broken cone with several pieces and barrancos on outer slope of the cone. Daheishan volcano has history of multiple eruptions, in which the original cone was broken apart by the later eruption that results in over 4 major pieces of the cone. Volcanic bombs with a diameter as large as 1m can be seen at the north rim, and volcanic agglomerate is developed in the south flank. This evidence indicates that an intensively explosive eruption once occurred. As the largest volcano in the basin, the main flows from Daheishan have broad extent of blocky lava. They reach the north mountain range, and run into and are covered by alluvia fans. Southward, the flows reach the Ashikule lake. Overall, Daheishan volcano is characterized by both overflow and explosive eruptions.

1.3 Wulukeshan Volcano

This volcano, also referred as volcano #3 in the previous work (Zhao Mingyu, 1976), lies 800m northeast of the Wuluke lake (Figs. 1b, 2d). The previous K-Ar dating result indicates that this volcano was formed about 0.2 Ma years ago (Liu Jiaqi et al., 1990). The cone of Wuluke volcano is basically well preserved, and barrancos are developed at the outer slope. The rim of the cone is sub-circular with a diameter of 220m. The north rim is about 30m higher than the south. The structure of the Wulukeshan volcano cone reveals at least three stages during its formation. In the early stage, the cinder cone was formed with the mixing of country rock debris, black and red-brown colored with a relatively gentle outer slope. In the middle stage, red brown splashdown accumulation was deposited around the rim. Unlike the Ashishan volcano, which has a steep inner slope, the inner slope of Wuluke cone is quite gentle, which reflects the long-term weathering process. In the last stage, ropy lava flowed towards the southwest, entering Wuluke lake and north to encounter Ashishan lava.

1.4 Yizishan Volcano

Yizishan volcano lies on a hillside west of the Wuluke lake (Figs. 1b, 2e). The previous K-Ar dating result indicates that this volcano was formed in about 0.58Ma years ago (Liu Jiaqi et al., 1990). "Yizi" means chair in Chinese, which indicates that the Yizishan cone is a "chair-like" shape with an outlet in NE direction. The inner crater rim is 150m long in the ES direction and 210m long in the NS direction. A lava flow unit in a "tongue-shape" can be clearly recognized through the satellite image. Inside the rim, there are massive collapses, where lava cakes and splashdown accumulation can be seen. The unique geomorphologic location of the Yizishan volcano, which is quite different from that of most volcanoes in the basin, implies that the development of the Yizishan volcano was controlled by the regional fault system.

1.5 Migongshan Volcano

Migongshan volcano lies on a hillside 500m east of the Wulukeshan volcano (Figs. 1b, 2f). The previous K-Ar dating result indicates that this volcano was formed about 0.44Ma years ago

Fig. 2

Some typical volcano cones and lava terraces of Ashikule volcano group

(a) Ashishan volcano (view SW); (b) Volcanic gas vent of Ashishan; (c) Daheishan volcano (view N); (d) Wulude volcano (view NW); (e) Yizishan volcano (view SW); (f) Migongshan volcano (view E); (g) Yueyashan volcano (view SW); (h) Maoniushan volcano (view S); (i) Matishan volcano (view N); (j) Dongshan lava terrace; (k) Xishan lava terrace; (l) Cross-section along Maoniushan lava valley (view SE); (m) Volcanic chain in NE direction (view N)

(Liu Jiaqi et al., 1990). Like the Yizishan cone, Migongshan is also a "chair-like" cone with an outlet about 130m wide. The "tongue-shaped" lava flows out from the break. Lava cakes are well developed around the rim of the cone, and massive collapse materials can be seen in the

inner rim. The major flow direction of the Migongshan lava is toward north, whereas the minor flow is southwest.

1.6 Yueyashan Volcano

Yueyashan volcano is located about 3km northeast of the Wuluke volcano (Figs. 1b, 2g). Previous K–Ar dating indicates that this volcano was formed about 0.31Ma years ago (Liu Jiaqi et al., 1990). "Yueya" means half moon in Chinese, suggesting a "crescent-shaped" cone. The rim of the Yueyashan cone is 70m × 90m. Due to strong weathering processes, the rim of the cone flattens. Later lava, flowing out from the north break of the cone, is covered by the alluvial fans.

1.7 Maoniushan Volcano

Maoniushan volcano is located about 720m northeast of the Yueyashan volcano (Figs. 1b, 2h). The formation time of this volcano is unclear so far. The rim of the Yueyashan cone is 410m × 310m in diameter. Due to strong weathering processes, the rim of the cone becomes butterfly-shaped and flat. The lava originally flowed towards the north, then west after rounding the hill.

1.8 Matishan Volcano

Matishan volcano is located on the northeast part of the Ashikule basin (Figs. 1b, 2i). The previous K–Ar dating result indicates that this volcano was formed in about 1.63Ma years ago (Liu Jiaqi et al., 1990). Most part of this volcano is covered by alluvial fans, and the partially exposed part appears in a "horse-shoe" shape, that is the meaning of "Mati" in Chinese. The north rim is about 30m higher than the south. The whole exposed part of the cone is 10m to 30m high above the alluvial fan. A parasitic volcano is found at the northeast slope of the cone. A cross-section at the south slope of the cone reveals 3 layers from the bottom to the top, i.e. a 2m thick red brown magma mass at the bottom; 1m thick volcanic cinder with abundant pores in the middle; and red magma mass again at the top. Such a formation succession indicates the explosive intensity changed from weak to strong, then from strong to weak again.

1.9 Dongshan Lava Terrace

Dongshan lava terrace lies on the eastern part of the basin (Figs. 1b, 2j). No volcanic crater was found in the field investigation. Instead, the undulated lava terrace with lava lobes and lava valley is well developed. The previous K–Ar dating of lava shows a formation age of 0.52 Ma years (Liu Jiaqi et al., 1990). This lava terrace covers a total area of 6km^2 at an altitude between 4640m to 4680m. The minimum thickness of the terrace is about 37m based on the field survey. The surface of the terrace has been seriously weathered and dark porous lava particles in a diameter of 1~5cm can be observed on the surface. The Dongshan lava terrace is the product of the overflow eruption of the Dongshan volcano.

1.10 Xishan Lava Terrace

Xishan lava terrace lies on the western part of the basin (Figs. 1b, 2k), 18km away from Daheishan volcano. The previous K–Ar dating of lava shows a formation age of 2.8 Ma years, the oldest volcanic rock in the basin (Liu Jiaqi et al., 1990). Like the Dongshan lava terrace, no volcanic crater can be found. This lava terrace covers a total area of 0.3km^2 at an altitude between 4969m to 4996m, the highest lava terrace in the basin. The thickness of the terrace is about 20m. On the surface of the terrace that has been seriously weathered, dark porous lava particles in a diameter of 1~5cm with maximum of 5cm can be seen.

1.11 Binhu Volcanic Chain

Binhu volcanic chain, located at the southwest coast of Wuluke lake, consists of 6 round hills in a northeast array (Fig. 1b). Among this chain, Gaotaishan is the largest one and is located at the northern most of the chain. Gaotaishan used to be interpreted as a rhyolitic porphyry based on the satellite image by Liu Jiaqi (see part 8, chapter 2, Active Volcano in China). However, the in-situ field investigation by our study reveals that Gaotaishan has no volcanic origin, but is in sedimentary rock with a bedding structure. All other hills with a "volcanic cone appearance" are lithologically characterized by acidic igneous rock with phenocrysts as large as 2cm. There is no doubt that further work is needed regarding the volcanic source of the Binhu volcanic chain.

1.12 Sub-volcanic Cones and Chains

Besides the major volcanoes mentioned above, there are hundreds of sub-volcanic cones and chains developed in the basin. These sub-volcanic cones are basically smaller in size (about 10 ~ 20m of diameters at cone base) and lower in height (from several meters to tens of meters), compared to the major volcanic cones. The formation of these sub-volcanic cones comes predominantly from dark-colored splashdown deposits which are from the weak explosive eruptions. The spatial distribution of these sub-volcanic cones is in a typically linear manner in the northeast direction, which is a clear indication of regional tectonically controlled volcanism. It is also worth noting that some of these cones have been cut off into small pieces, which reflects the strong neotectonic activity after the intensive volcanic activity in the Ashikule basin.

2 PRELIMINARY CONCLUSION

The eruption mode of the Ashikule volcano group is various in different eruption episodes as well as for different volcanoes. It can be summarized into two major modes, i. e. explosive eruption during the formation of volcanic cones and subsequent lava overflow.

There is a close relationship between volcanic activity in the Ashikule basin and regional tectonic activity. Specifically, the linear distribution of some volcanoes results from the effect of regional fault activity, such as the NE-trending Altyn fault and ES-trending Kangxiwa fault. Moreover, it has been observed that some original volcanic features have been altered by the later neo-tectonic activity.

Based on the preliminary field survey of geological and geomorphological features of the Ashikule volcano group, the volcanism process in the Ashikule basin can be divided into three episodes. The first episode starts from the Pliocene epoch to early Pleistocene epoch, as in the examples of the Xishan, Dongshan and Matishan volcanoes. The typical volcanic product in this episode is represented by a strongly weathered lava terrace and volcanic cone remnant. The second episode is in the middle Pleistocene, as represented by the Daheishan, Migongshan, Yizishan, Maoniushan and Yueyashan volcanoes, which are characterized by broken volcanic cones and moderately weathered lava flows. The third episode starts from the late Pleistocene to Holocene, as represented by the Ashishan and Wulukeshan volcanoes, which are characterized by well preserved volcanic cones and less weathered lava flows.

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REFERENCES

Deng Wanming. *Cenozoic Intraplate Volcanic Rocks in the Northern Qinghai-Xizang Plateau* [M]. Beijing: Geology Geological Publishing House, 1998. 36 ~ 37, 162 ~ 164 (in Chinese).

Deng Wanming. Geological investigation on the volcanic group in the Wulukekule (lake) region, Xinjiang: Query the validity of "the eruption of No. 1 volcano in 1951" [J]. *Acta Natural Resources*, 1989, 4(4):349 ~ 354 (in Chinese with English abstract)

Li Shuanke. Study on the geomorphology and Quaternary geology of the Ashikule basin, middle Kunlun Mountains [J]. *Acta Geographica Sinica*, 1991, 46(2): 224 ~ 232 (in Chinese with English abstract).

Liu Jiaqi. *Volcano in China* [M]. Beijing: Science Press, 1999. 44 ~ 46 (in Chinese).

Liu Jiaqi and Yiming Maimaiti. K-Ar age and distribution of Xikunlun Volcano in Quaternary [J]. *Science in China* (*Earth Sciences*), 1990, (2):180 ~ 187 (in Chinese with English abstract).

Liu Ruoxin. *Active Volcano in China* [M]. Beijing: Science Press, 2000. 81 ~ 88 (in Chinese).

Xinjiang Daily. *Volcano Eruption Occurred in the Western Valley of Kunlun Mountains, Southern Xinjiang* [Z]. May 7, 1951, page 2 (in Chinese).

Zhao Mingyu. Introduction on Ashikule active volcanoes and the Quaternary volcano groups in Kunlun Mountains of Xinjiang [J]. *Xinjiang Geology*, 1976, (1 ~ 2): 27 ~ 36 (in Chinese).

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