Discovery and character of the Kunlun-Yellow River Movement

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Abstract Based on geomorphological, tectonic and sedimentary data, a Kunlun Yellow River Tectonic Movement has been recognized in 1.10—0.60 Ma B.P. This tectonic movement, which leads to uplift of the Qinghai-Xizang (Tibet) Plateau from 1 500 to 3 000—3 500 m, is periodic, abrupt and changeable in the movement rate of uplifting and slide slipping.

Keywords: Kunlun Mountain Pass, 700 kaB.P., tectonic movement.

1 Discovery of the Kunlun-Yellow River (KY) Movement

THE Kunlun Pass area is located in the central part of the Qinghai-Xizang (Tibet) Plateau on the border between the Qiangtang Plateau and the Qaidam Basin. Tremendous environmental change has occurred since the Middle Pleistocene.

A 700-m sequence from the Pliocene to the Middle Pleistocene is exposed around the former No. 62 Maintenance Squad on the Qinghai-Xizang Highway. Analysis on lithology, sedimentary structure, stratigraphic sequence, paleocurrent and the pattern of sediment and composition suggests that there are alluvial fan sequence (Jingxiangu Formation), lacustrine system and fan delta sequence (Qiangtang Formation)[1, 2]. The environment changed from hot to cool in 2.5 MaB.P., and accordingly the sediments changed from the Jingxiangu Formation to the Qiangtang Formation gradually. The sedimentation of the Qiangtang Formation ended at 0.73 MaB.P. All the strata were tilted southwest by a tectonic movement at an angle of about 12° (fig. 1). The unconformity between the Wangkun till sheet (0.71 MaB.P.) and the underlying Qiangtang Formation suggests a violent tectonic movement occurring during 0.71—0.6 MaB.P. in east Kunlun Mountains (including the Kunlun Pass area). This movement resulted in the formation of the discordant till sheet and the equivalent sediments in the Kunlun fault valley, including the

Naij Tal Gou Formation (0.64 MaB.P., mainly debris flow facies) and the Sanchahe Formation (0.4—0.6 MaB.P., mainly alluvial facies). According to the information of core RH in the Zoige Basin studied by Wang Suming, sedimentary facies and environment changed greatly during 0.7—0.5 MaB.P. Both the Kunlun Pass area and the Zoige Basin belong to Xidatang-Maqu strike-slip fault belt, though the two areas are about 1 500 km apart. Analysis of palynoflora, Ostracoda and mollusk fossils shows a warm and humid environment, and an elevation of 1 500 m at that time[3]. Because of the existence of planation surface and palaeokarst (18.0—7.0 MaB.P.), the elevation should have been 1 000 m during the Miocene Epoch[4].

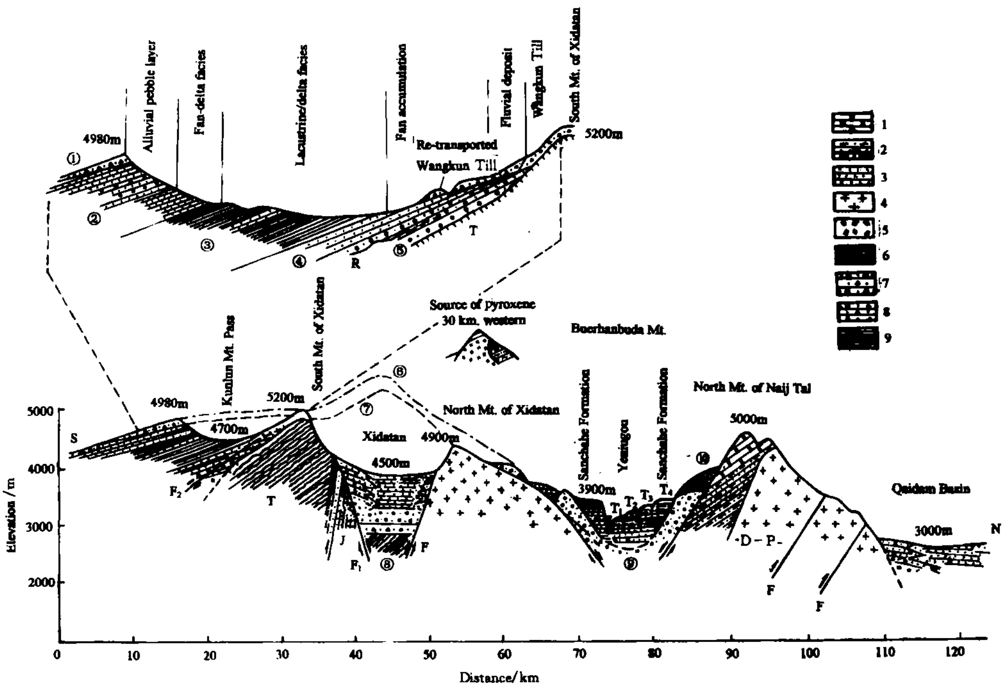

Fig. 1. Structure, geomorphology and stratigraphical sections during the Cenozoic in Kunlun Pass area, China. 1, Marble; 2, basalt and volcanic rock; 3, phyllite, slate and schist; 4, granitoid; 5, pyroxene; 6, sandy shale; 7, till; 8, river and debris-flow accumulation; 9, lacutrine deposit. ① Wangkun Till (discordant), 10—20 m thick, 710 ka; ② Pingtai Fm. (1.1—0.8 Ma); ③ Qiangtang Fm. (2.4—1.1 Ma); ④ Jingxiangu Fm. (3.4—2.4 Ma); ⑤ Kunlun pebble layer (>3.4 Ma); ⑥ range of Wangkun Glaciation; ⑦ summit line before the formation of Xidatan Valley; ⑧ upper, Sanchahe Fm., 170—300 m thick, 600—350 Ma; middle, inferred Naij Tal Gou Fm.; Lower, inferred Wangkun Till; ⑨ Upper, Sanchahe Fm.; lower, Naij Tal Gou Fm., about 100 m thick, 640—400 Ma; ⑩ Xiaonanchuan section, 20 m thick, 60—3 ka. R, Red weathering residue; J, compressional fracture zone; F_1, Xidatan-Maqu strike-slip fault; F_2, Kunlun Mt. Pass strike-slip fault.

After the Middle Pleistocene, the main strata in this area are the Naij Tal Gou Formation and the Sanchahe Formation. The Naij Tal Gou Formation, 100 m in thickness, is composed mainly of debris flow and distributed around Naij Tal, with the type section at the Hougou of Naij Tal. The Sanchahe Formation is distributed in the Dongdatan, Xidatan, Xiaonanchuan and Yeniugou valleys. The maximum thickness of the Sanchahe Formation is about 300 m in the Xidatan Valley (according to geophysical prospecting). It is an alluvial bed formed in the Middle and the Late Pleistocene. The sporopollens of the Sanchahe Formation are mainly Chenopodiaceae, *Ephedra*, Gramineae and *Artemisia*. This fact suggests a dry environment. The species of Ostracoda in the Sanchahe Formation are similar to those in the present condition. This suggests a high elevation and adverse situation after the Middle Pleistocene. In all respects, similar fauna assemblages in the Sanchahe Formation and in the present condition suggest that the elevation was about 3 500—4 000 m in 0.4 MaB.P. It shows a little difference from present situation but a tremendous difference from that when the Qiangtang Formation was formed, i.e. before the K-Y River Movement.

Tremendously environmental changes occurred at the turn between the Early and the Middle Pleistocene, and the Pass Basin uplifted from 1 500 to 4 700 m since the Pleistocene. Therefore, it is concluded that there must have been a violent tectonic movement. Almost all of the uplift of the Qinghai-Xizang Plateau and the pattern of landform in Kunlun Pass area resulted from this movement in the Middle Pleistocene; in addition, the around areas were greatly affected at the same time. This tectonic movement was originally named the Kunlun Movement, and renamed the Kunlun-Yellow River Movement according to suggestion of Prof. Li Jijun because the Kunlun Movement and Yellow River Movement occurred at almost the same time.

2 The character of the KY Movement

2.1 Stages of the KY Movement

Different methods were used to date the age of the Kunlun-Yellow River Movement, such as electronic spin resonance (ESR) dating, paleomagnetic measuring and thermoluminescence (TL). The detail analysis shows that the K-Y River Movement started at 1.1 MaB.P., and included three stages: prologue episode, main episode and continuous episode (table 1).

Table 1 Stages and character of the KY Movement

Stage	Age/Ma	Type of tectonic movement	Force field	Typical structure and landform	Sedimentary facies and stratigraphy
Prologue episode	1.1—0.7 (ESR) (TL)	discontinuous whole uplift	tenso-shear and compresso-shear	Kunlun River reversed fault, denuded surface and red paleosol on the top of Qiangtang Fm.	lacustrine clay in the middle of Qiangtang Fm. changing to gravel of alluvial and fan-delta, lake disappeared
Main episode	0.7—0.65 (ESR) (PM)(TL)	Accelerating uplift of the mountains, block depression	compresso-shear	Qiangtang Fm. and around area uplifted to mountains (e.g. Boerhanboda); Wangkun Glaciation and fault valley (Kunlun River valley) formed	alluvial gravel on the top of Qiangtang Fm. covered by Wangkun till sheet, Naij Tal Gou alluvial stratum formed
Continuous episode	0.65—0.6 (TL)	first block uplift and depression, then horizontal strike-slip	compresso-shear	top of the Boerhanboda depressed into Xidatan Valley, Wangkun till sheet was uplifted to the top of mountains, Xidatan Valley formed, with no-head fault valley, mole structure, fault cliff and fault spring in Xidatan Valley	alluvial facies and aeolian facies sediment in the Sanchahe Fm. formed

2.2 Abruptness of the KY Movement

Thin-bedded red paleosol and thick-bedded plant remnant (with a maximum thickness of about 0.5 m) were found in the fan-delta gravel (0.7 MaB.P.) during the field work. Its sporopollen assemblage, including Chenopodiaceae, *Ephedra*, *Artemisia* and other herbs, suggests that there might be a grassland vegetation, so its climate was warmer than before. Furthermore, several kinds of exotic tree pollen were found in this bed[2]. It is interesting that a similar assemblage of sporepollen comes from the underlying stratum. The abnormal warm and humid climate indicated by red paleosol and the sporopollen indicates that there might be a warm climatic period before the last but two glaciation. The existence of red paleosol shows a sedimentary hiatus, i.e. a change from deposited area to denuded area due to uplift. In other words, the main episode of the KY Movement was sudden, i.e. it was slowly uplifted during 1.1.—0.7 MaB.P. and violently uplifted at 0.7 MaB.P. If not so, it is very difficult to explain the appearance of the discordant till sheet after a period of warm and sedimentary hiatus.

2.3 Simultaneousness of the Wangkun Glaciation and KY Movement

All of the tectonic and climatic events since the Neogene Period show that "gradual change" and "sudden change" have taken place alternately, but the violent KY Movement did not stop during and after the Wangkun Glaciation. Both of them ran during 0.7—0.6 MaB.P. The till sheet of Wangkun Glaciation distributed originally at the southern foot of the mountain was uplifted to the top (4 900—5 000 m a.s.l.) of the Boerhanboda Mountains by the movement. Taking 3 300 m a.s.l. as the elevation of the primary till sheet on the northern slope of the Kunlun Mountains (perhaps the difference between southern and northern slopes is about 200—300 m, the original elevation of the till sheet in the southern slope might be 3 500 m), the till sheets on the top of the mountains have been uplifted at least 1 500 m since the Middle Pleistocene.

2.4 Variable uplift rate and strike-slip speed

Table 2 shows the uplift time and rate in the Kunlun Pass area. During 7.0—1.1 MaB.P., before the movement, the Pass area was uplifted and degraded. The alluvial fan and lacustrine sediments of the Qiangtang Formation show this. The mean uplift rate was less than 0.01 mm/a. In the prologue episode (1.1—0.7 MaB.P.), the mean uplift rate was 3.73 mm/a, very close to 3.3 mm/a——the modern mean uplift rate; but in the main and continuous episodes, the mean uplift rate was as high as 23 mm/a, faster than that of the main episode. After He Qunlu, the strike-slip rate of the Xidatan Fault and the Kunlun Pass Fault was 10—15 mm/a. From the fact that the pyroxenite boulders of the Wangkun till sheet have been moved 30 km eastward from its source region since 0.7 MaB.P., it is inferred that the mean strike-slip speed of Xidatan Fault was 40—50 mm/a. Because of a mistaken interpretation of the origin of the pyroxenite gravel in the bottom of the Jingxiangu Formation, some scholars[5] thought that the pyroxenite boulders were deposited before 3 Ma, so the 10 mm/a strike-slip speed is suspicious. The Kunlun Pass Fault formed in the Post Glaciation has become one of the main faults in this area. According to the displacement of the Late Glaciation till sheet, the strike-slip speed of the Kunlun Pass Fault was about 10—15 mm/a in the last 10 ka.

Table 2 The uplift time and uplift speed of the KY Movement

Time interval/Ma B.P.	Uplift range/m	Mean uplift speed/$mm \cdot a^{-1}$
7.0—1.1	(1 000—1 500)500	<0.01
1.1—0.7	(1 500—3 000)1 500	3.75
0.7—0.06	(3 000—4 500)1 500	2.5
0.06—now	(4 500—4 700)200	3.3

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