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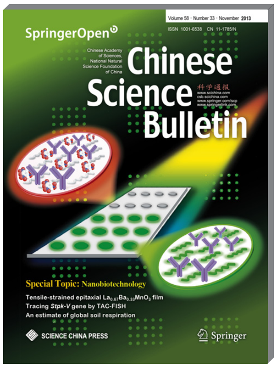

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COVER Microarray analysis plays an important role in modern biology and medicine because it offers high throughput and the ability to detect multiple signals. Fluorescent conjugated polymers have been successfully used in microarray-based assays. A new strategy to fabricate conjugated polymer microarrays with proteins is illustrated on the cover. Protein molecules act as promoters to increase the amount and the stability of cationic conjugated polymers on the substrate via electrostatic association and hydrophobic interactions, as well as providing an anchor unit to bind to the surface. Our microarray is easy to fabricate, as no chemical linking is required between the conjugated polymer and microarray substrate. The fluorescent images of the conjugated polymer microarray are shown. We used our conjugated polymer microarray to detect 2, 4, 6-trinitrophenol (picric acid). The fluorescence is quenched by picric acid via electron donor-acceptor interactions. We anticipate that other novel sensing platforms can be constructed based on this facile and versatile microarray (see the article by LÜ FengTing et al. on page 4039).

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Modern pollen and vegetation relationships in the Yili Basin, Xinjiang, NW China

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Fifty-six surface pollen samples from different vegetation zones in the Yili Basin, western Tianshan Mountains, Xinjiang were analyzed to examine the relationships between the surface pollen assemblages and the original vegetation. A pollen analysis and a vegetation investigation with a discriminant analysis show that the pollen assemblages greatly differ across disparate vegetation zones. Twelve pollen taxa can be used as significant types for vegetation reconstruction in the basin. These taxa were the most abundant in the surface pollen samples. Cupressaceae pollen percentages were greater than 1% in Cupressaceae shrubs. More than 5% of *Picea* pollen indicates the growth of a *Picea* forest within 5 km. The subalpine meadow that is distributed widely in the basin is characterized by high content of *Artemisia*, Chenopodiaceae, Poaceae, *Picea*, Asteraceae, *Taraxacum* and *Arenaria* pollen types. The *Artemisia*-Chenopodiaceae-Poaceae-Cannabaceae pollen assemblages indicate the presence of montane steppe in the area. *Artemisia* and Chenopodiaceae pollen dominate the desert steppe and *Populus* forest. *Artemisia* pollen percentages were greater than 60% in the *Artemisia* desert, whereas Chenopodiaceae pollen percentages exceeded 65% in the Chenopodiaceae desert. The *Artemisia*/Chenopodiaceae (A/C) ratios reflect the vertical moisture changes in the Yili Basin. The mean A/C ratios were greater than 1.2 in the subalpine meadow and montane steppe that occupy the humid zone in the basin. These ratios were between 1 and 1.2 in the Cupressaceae shrubs, desert steppe, *Populus* forest and floodplain meadow. The ratios were less than 0.5 in the Chenopodiaceae desert, which is an arid environment.

Tianshan Mountains, Yili Basin, modern pollen and vegetation, discriminant analysis, A/C ratios

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Understanding the relationships between modern pollen and vegetation is a prerequisite for interpreting the fossil pollen records correctly, thereby improving the accuracy of past vegetation types and climate reconstruction [1–5]. Xinjiang is situated in the arid area of central Asia, which has been a hot spot for paleovegetation and paleoclimate research given its fragile ecology and sensitive response to climate change [6–9]. Modern pollen rain studies in Xinjiang have generated much attention over the past several decades [10–18]. Yan and Xu [12] reported the characteristics of modern pollen distribution in different vegetation zones in the Altai Mountains. Weng et al. [13] investigated the relationships between surface pollen assemblages and the vegetation zone as well as the significance of the *Artemisia*/Chenopodiaceae (A/C) ratios from the West Kunlun Mountains. Pan [14] examined the pollen assemblages of different vegetation types from the northern slope of the Tianshan Mountains. Xu et al. [15] discussed the numerical relationship between the main pollen taxa and vegetation coverage from the southern slope of the Tianshan Mountains. Yan et al. [16] and Yang et al. [17] studied the distribution of surface pollen from the source area of the Urumqi River at the Tianshan Mountains. Luo et al. [18] examined the modern pollen distribution and its relationship to vegetation communities in the Xinjiang region, and suggested that the different vegetation formations have unique assemblages that can be statistically distinguished.

The Tianshan Mountains are one of the largest mountain

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ranges in central Asia; as such, the Tianshan Mountains possess a complicated vertical vegetation zone and creates a natural geographic boundary in the Xinjiang region. At present, most modern pollen studies have been reported in the middle and eastern portions of the Tianshan Mountains. However, little research has been conducted on the modern pollen in the western mountains. Yili Basin, one of the places with the most precipitation in the Xinjiang region, lies in the western section of the Tianshan Mountains. Due to its luxuriant forest, meadow vegetation and complete vertical vegetation zone, the basin is an ideal place for modern pollen study. The current study investigates the modern pollen of the different vegetation zones in the Yili Basin to discuss the characteristics of their assemblages and the significance of the A/C ratios in the basin. Our aim is to collect basic data to understand the relationships among pollen, vegetation and climate in central Asia.

1 Study region

The Yili Basin (42°41′–44°50′N, 80°09′–84°56′E) is an intramontane basin in the western section of the Tianshan Mountains in central Asia. This basin has a temperate, semiarid continental climate and is dominated by westerly winds throughout the year. The basin is in a relatively high precipitation zone of Xinjiang due to its exposure to the humid and warm airflow from the west. The mean annual temperature varies from 2.6 to 9.2°C depending on the terrain. The mean annual precipitation is between 200 and 500 mm on the plains but can reach 800 mm in the middle zone of mountains [19,20]. The vertical vegetation zones possess an evident and complete structure. Classified from top to bottom, this structure includes an alpine cushion-like vegetation zone, an alpine meadow zone, a subalpine meadow zone, a montane forest-meadow zone, a montane steppe and a desert zone [21,22] (Figure 1). Details of the vegetation zones in the basin are described below.

(1) The alpine cushion-like vegetation zone occurs between 3000–4000 m a.s.l. and is dominated by *Thylacospermum caespitosum* and *Potentilla biflora*.

(2) The alpine meadow zone occurs between ~2800–3500 m a.s.l. and is composed of *Cobresia capilliforms*, *Carex stenocarpa*, *C. cobressiformis* and *Polygonum viviparum*.

(3) The subalpine meadow zone occurs from ~2000 to 2800 m a.s.l. and is dominated by *Alchemilla obtuse*, *Alchemilla rubens*, *Geranium pseudosibiricum*, *Iris ruthenica*. *Poa annua*, *Cobresia capilliforms*, *Festuca coelestis* and *Thalictrum alpinum*. *Gentiana tianschenica* are also abundant in this zone.

(4) Patches of the *Picea schrenkiana* forest zone combined with steppe or meadow occur on shady and wet mountain slopes between ~1700–2800 m a.s.l. *Helictotrichon pubescens*, *Festuca rupicola* and *Helictotrichon tianschanicum* dominate the undergrowth plants in the *Picea* forest.

(5) The montane steppe zone occurs on the piedmont between ~1000–2000 m a.s.l. and consists predominantly of *Stipa kirghisorum*, *S. lessingiana* and *S. purpurea*. *Festuca ovina*, *Agropyron cristatum*, *Leymus tianschanicus*, *Potentilla bifurca* are also common in this zone.

(6) The desert steppe zone occurs below ~1200 m a.s.l. and is dominated by *Festuca ovina*, *Seriphidium transiliense*, *Bothriochloa ischaemum*, *S. capillata*, *S. caucasica*, *S. sareptana*, *Kochia prostrate* and *Ceratocarpus arenarius*.

(7) The montane desert zone can be divided into two types: The *Artemisia* desert (below ~1200 m) is dominated by *Seriphidium transiliense*, *Kochia prostrate* and *Polygonum aviculare*; the Chenopodiaceae desert (between ~800–1000 m) is dominated by *Chenopodium glaucum*, *Ceratocarpus arenarius*, *Seriphidium transiliense*, *Nanopgyton erinaceum* and *Kochia prostrate*.

(8) The *Populus* forest and floodplain meadow is distributed across the river floodplain and lowland with high groundwater level. The vegetation types include the *Populus*

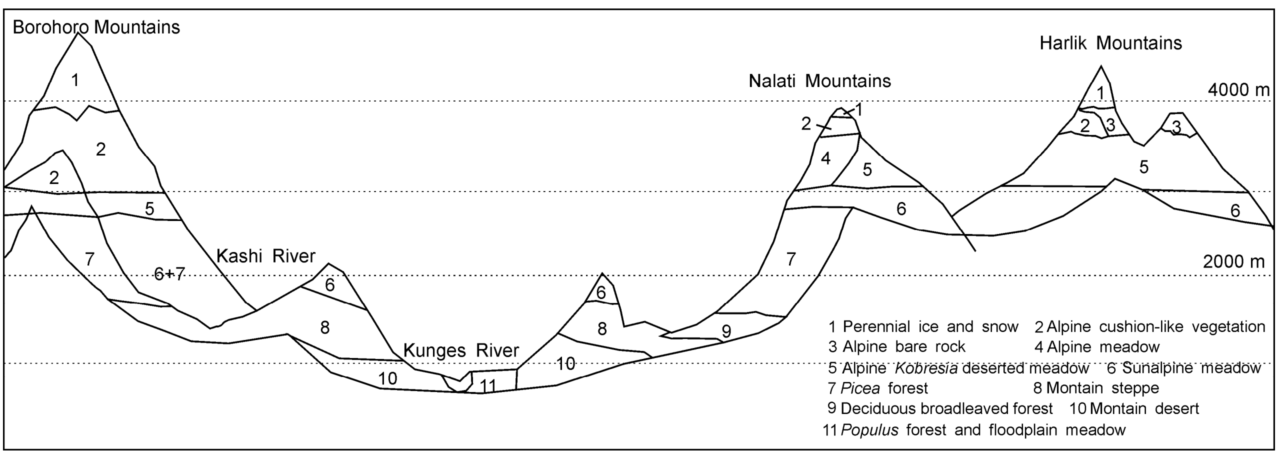

Figure 1 Vertical vegetation zone in the Yili Basin [21].

euphratica, *Phragmites australis*, *Achnatherum splendens* and *Typha* communities.

2 Materials and methods

Fifty-six topsoil (0–2 cm) samples were collected from different sites including 3 samples from Cupressaceae shrubs, 5 from the *Picea schrenkiana* forest, 17 from the subalpine meadow, 12 from the montane steppe, 4 from the desert steppe, 7 from the *Artemisia* desert, 2 from the *Populus euphratica* forest and 4 from the floodplain meadow where human disturbance is negligible in the Keguqin, Borohoro and Wusun Mountains (Figure 2). The plot areas of the spruce forest, shrub, steppe or meadow and desert zones are 10 m×10 m, 5 m×5 m, 1 m×1 m and 5 m×5 m, respectively. The samples were collected randomly for each plot.

All 30-g samples were used to prepare the pollen residues in the laboratory. The pollen was concentrated using the acid-alkali-acid method including 10% HCl, 5% KOH, 40% HF, acetolysis treatments and sieved through a 7-μm screen to remove clay-sized particles [23]. Lycopodium tablets were added to the samples to estimate the pollen concentrations. At least 400 pollen grains using more than two slides were counted in each sample.

Discriminant analysis is an effective method of investigating the quantitative relationship between modern pollen assemblages and vegetation [24–26]. First, the modern samples are divided into different groups consistent with the vegetation types at the sample locations. Then, the discriminant functions are established based on the pollen percentages in each sample. These functions are used for cross-testing to classify each sample into a different vegetation type to obtain predicted groups. If the predicted result is consistent with the a priori group, then the pollen assemblages are sufficiently representative vegetation types. SPSS 19 was used to perform the discriminant analysis.

3 Results

One hundred five pollen taxa were identified across 56 topsoil samples from the Yili Basin. The most abundant arboreal pollen taxa include *Pinus*, *Picea*, *Betula*, *Quercus*, and *Ulmus*, and so on. Shrub pollen taxa primarily included Cupressaceae, *Salix*, *Caragana*, *Ephedra*, *Hippophae*, and so on. Herb pollen types primarily include *Artemisia*, Chenopodiaceae, Poaceae, Asteraceae, *Aster*, *Taraxacum*, Rosaceae, Fabaceae, *Geranium*, Cyperaceae, *Arenaria*, *Sparganium* and *Typha*, and so on. Pollen percentages are calculated using the sum of the arboreal and non-arboreal pollen (shrub and herb) taxa identified in each sample. The taxa greater than 0.5% are shown in Figure 3.

3.1 Modern pollen assemblages across different vegetation zones

Artemisia (mean 39%) and Chenopodiaceae (35%) dominated the modern pollen assemblages from the Cupressaceae shrub zone. However, the Cupressaceae pollen content ranged from 0.4% to 2.7%, with a mean of 1.4%. The percentages of *Picea* (8.3%) and Poaceae (2.9%) pollen

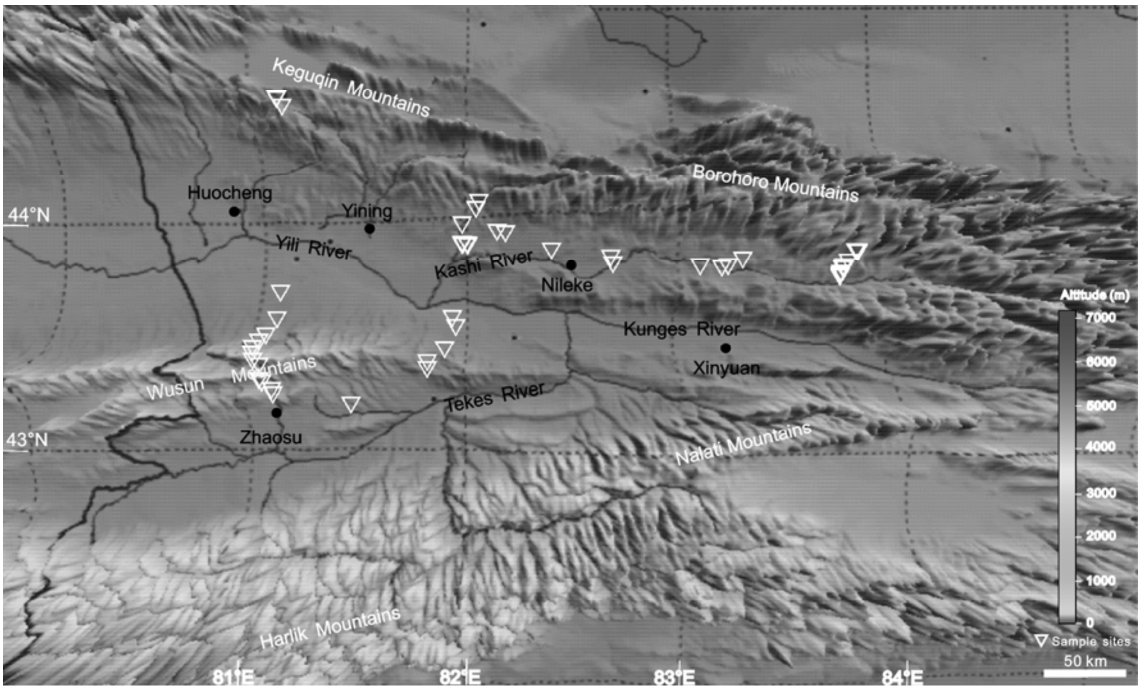

Figure 2 Modern pollen sample sites in the Yili Basin.

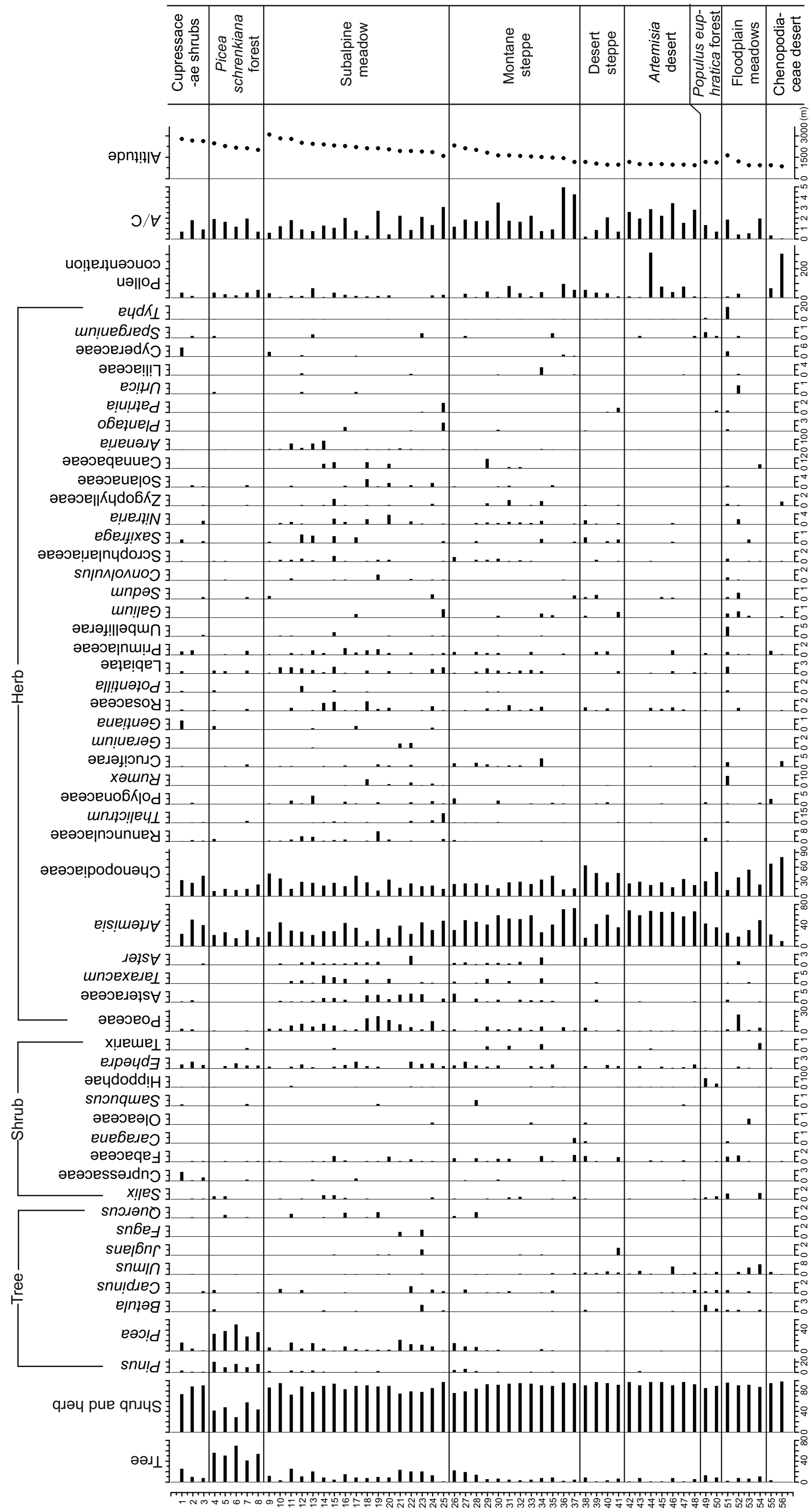

Figure 3 Modern pollen percentages in the Yili Basin.

were relative high. The A/C ratios range from 0.7 to 1.9, with a mean of 1.2.

The modern pollen assemblages from the *Picea schrenkiana* forest were characterized by their high content of *Picea* pollen (maximum 51.6%, mean 37.9%). The mean percentage of *Pinus* pollen was 14.8%, and the maximum was 20.8%. The *Artemisia* (23%) and Chenopodiaceae (16.3%) pollen were relatively low in this zone. The mean percentage of Poaceae pollen content was 1%. The other taxa percentages were less than 1%. The A/C ratios ranged from 0.7 to 2 with a mean of 1.5%.

The pollen assemblages of subalpine meadow were characterized by their high content of *Artemisia* (32.2%), Chenopodiaceae (26.8%) and Poaceae (9.7%). The pollen content of Asteraceae, *Taraxacum*, Ranunculaceae, *Thalictrum*, *Aster*, Polygonaceae, *Rumex* and *Arenaria* were higher than that of other vegetation types. A few Rosaceae, Lamiaceae, Primulaceae and Saxifragaceae pollens appeared in the samples. Cyperaceae pollen was found in several samples, with a maximum of 2.9%. The *Picea* pollen maximum content was 7.9% due to the spruce forest close to the meadow. The A/C ratios ranged between 0.4 and 3.1, with a mean of 1.4.

In the montane steppe zone, the *Artemisia* pollen percentages (50.8%) clearly increased, whereas the Chenopodiaceae (26.4%) pollen content changed little compared with the subalpine meadow zone. The maximum Poaceae pollen percentage was 7.9%, with a mean of 3.8%. The Asteraceae (1%) and *Taraxacum* (0.7%) pollen content decreased. The peak values of Cruciferae, Cannabaceae and Liliaceae pollen content occurred in this zone. The *Picea* pollen percentages clearly decreased. The A/C ratios ranged from 0.8 to 5, with a mean of 2.2.

Artemisia (39.4%) and Chenopodiaceae (47.6%) dominated the modern pollen assemblages from the desert steppe. The *Artemisia* pollen content decreased, whereas the Chenopodiaceae pollen content increased compared with the montane steppe zone. The Poaceae pollen percentages (mean 2.7%, maximum 5.7%) were relative low compared with the subalpine meadow and montane steppe zones. The *Picea* pollen content was low with a mean of 0.6%. The maximum *Ulmus* content was 2.3%, with a mean of 1.7%. The A/C ratios ranged from 0.3 to 2.1, with a mean of 1.

The pollen taxa from the *Artemisia* desert zone were homogenous. *Artemisia* pollen dominated the pollen assemblages (65.1%), and the Chenopodiaceae pollen percentage was only 26.9%. The Poaceae pollen content decreased by a mean of 0.8%. The maximum *Ulmus* content was 6% with a mean of 1.8%. The other pollen taxa in this zone were less than 1%. The A/C ratios ranged from 1.6 to 3.5 with a mean of 2.5.

Artemisia (40.4%) and Chenopodiaceae (41.4%) dominated the modern pollen assemblages from the *Populus* forest. The mean content of *Hippophae* pollen was 6.2%, whereas the same value of *Typha* was 2.1%. The maximum *Ulmus* pollen percentage was 2.1%; however, no *Populus* pollen was found in this zone. The A/C ratios ranged from 0.7% to 1.4% with a mean of 1.1.

Artemisia (31.6%) and Chenopodiaceae (33.6%) also dominated the modern pollen assemblages from the floodplain meadow. In the *Phragmites* meadow, the pollen percentages of Poaceae, Asteraceae and *Aster* were 25.9%, 1.2% and 1%, respectively. In the *Typha* community, the eponymous pollen percentage was 19.2%; in addition, the percentages of *Rumex* (9.4%), *Thalictrum* (2.4%), Cruciferae (2.4%) and Umbelliferae (1.8%) pollen were relatively high. In the *Tamarix* communities, the pollen content of *Ulmus* (7.7%), *Salix* (1.2%), Poaceae (5.6%) and Cannabaceae (5.1%) was relatively high, whereas the *Tamarix* pollen content was only 0.7%. The A/C ratios ranged from 0.5% to 2%, with a mean of 1.2 in the floodplain meadow.

Chenopodiaceae pollen dominated the modern pollen assemblages from the Chenopodiaceae desert with a mean of 74.6%. The mean content of *Artemisia* pollen was only 17%. A few *Ulmus* (2%), Polygonaceae (2.7%), and Cruciferae (3%) pollens were found in this zone.

3.2 Discriminant analysis

Fifty-six samples were divided into nine groups (A–I) depending on the different vegetation zones in the Yili Basin (Table 1). The pollen taxa, whose content comprised more than 2% of at least one sample, were used for the discriminant analysis. The results of this analysis showed that 98.2% (55 of 56) of the samples were correctly classified into their original vegetation groups (Table 2), which indicates that the surface pollen from the basin represents the vegetation types well. The first two functions accounted for 72.9% of the total variance. The samples of Cupressaceae shrubs (A), *Picea schrenkiana* forest (B), desert steppe (E), *Populus euphratica* forest (G), floodplain meadow (H) and Chenopodiaceae desert (I) can be clearly discriminated using the first two functions (Figure 4). However, group centroids of subalpine meadow (C), montane steppe (D) and *Artemisia* desert (F) are close to each other, which might be

Table 1 The surface pollen groups for the discriminant analysis in the Yili Basin

Vegetation type	Group
Cupressaceae shrubs	A
Picea schrenkiana forest	B
Subalpine meadow	C
Montane steppe	D
Desert steppe	E
Artemisia desert	F
Populus euphratica forest	G
Floodplain meadow	H
Chenopodiaceae desert	I

caused by the high content of *Artemisia* pollen in the three vegetation types. Consequently, one montane steppe sample was misclassified as *Artemisia* desert (Table 2).

4 Discussion

4.1 The relationships between modern pollen assemblages and vegetation

This study of 56 topsoil samples from 9 vegetation types indicated that the major pollen taxa in the Yili Basin were *Picea*, Cupressaceae, *Ulmus*, *Artemisia*, Chenopodiaceae, Poaceae, Asteraceae, *Taraxacum*, *Arenaria*, Cannabaceae, *Hippophae* and *Typha*. These 12 taxa represent the main pollen types in the basin that can be used as the significant pollen taxa for paleovegetation and paleoclimate reconstruction in the basin. *Picea* pollen dominated the modern pollen assemblages from the *Picea schrenkiana* forest, whereas *Artemisia* and Chenopodiaceae pollen dominated other vegetation types including Cupressaceae shrubs, subalpine meadow, montane steppe, desert steppe, *Artemisia* desert, *Populus euphratica* forest, floodplain meadow and Chenopodiaceae desert in the basin.

Cupressaceae shrubs, which are dominated by *Sabina pseudosabin*a and *Juniperus sibirica*, grow on sunny or semi-sunny slope between 2500–3000 m a.s.l. in the basin. *Artemisia* and Chenopodiaceae dominate the pollen assemblages from Cupressaceae shrubs. This result is might be due to the valley breeze that bring *Artemisia* and Chenopodiaceae pollen from low to high altitudes in the basin. The presence of Cupressaceae pollen was low (maximum 3%), which shows that this pollen does not reflect the real proportion of its parent plant in the vegetation zone. Cupressaceae pollen, which appears in *Picea* forest, subalpine meadow and montane steppe and decreases at low altitudes, only exceeded 1% in the Cupressaceae shrubs. The surface pollen from the *Sabina* forest in the western Kunlun Mountains suggested that 5% *Sabina* pollen content indicates the presence of a *Sabina* forest, which shows an underrepresentation of Cupressaceae pollen [13].

Patches of *Picea schrenkiana* forests are distributed along the shady and wet slopes in the middle mountain region of the Yili Basin. The modern pollen assemblages in the *Picea schrenkiana* forest are characterized by the high content of *Picea*, *Pinus*, *Artemisia*, Chenopodiaceae and *Poaceae* pollens, whereas other pollen taxa did not exceed 1%. The *Picea schrenkiana* forest can be distinguished by the discriminant analysis easily. The content of *Picea* pollen was greatest in the *Picea schrenkiana* forest, and decreased with distance from the spruce forest. *Picea* pollen content comprised more than 5% of the modern pollen assemblages from the Cupressaceae shrubs and subalpine meadow zones that were less than 5 km from the *Picea* forest. This content ranged between 1% and 5% in the pollen assemblages from the montane steppe, whose distance ranged from 5 to 10 km. The content comprised less than 1% of the pollen assemblages from the desert steppe, *Artemisia* desert and Chenopodiaceae desert, which were more than 10 km away. The representation and distribution characteristics of the *Picea* pollen in the Yili Basin were similar to those of other regions in China [13,27–31].

The subalpine meadow, which possesses multiple plant species, is the most widely distributed zone in the Yili Basin. Its plants are primarily composed of *Alchemilla, Poa* and *Stipa* with various weeds. *Artemisia* and Chenopodiaceae dominate the pollen assemblages from the subalpine meadow; however, the abundant pollen taxa and high content of Poaceae pollen (mean 9.7%, maximum 23.3%) are most distinctive features in this zone. Rosaceae (especially *Alchemilla*) is the species that constructs the subalpine meadow; however, the Rosaceae pollen content was low (mean 0.5%, maximum 1.9%) and significantly below the proportion of its parent plant. The pollen content of Cyperaceae (maximum 2.9%) was low due to the few Cyperaceae plants in the subalpine meadow. The characteristics of the pollen assemblages from the subalpine meadow in the basin were similar to those in the western Kunlun Mountains [13].

Stipa and *Festuca* are constructive vegetation in the montane steppe of the basin. These vegetation coverage and pollen taxa clearly decreased compared with the subalpine

Table 2 The discriminant analysis results of the modern pollen assemblages in the Yili Basin

Actual groups	Samples	Predicted groups								
		A	B	C	D	E	F	G	H	I
A	3	3 (100%)	0	0	0	0	0	0	0	0
B	5	0	5 (100%)	0	0	0	0	0	0	0
C	17	0	0	17 (100%)	0	0	0	0	0	0
D	12	0	0	0	11 (91.7%)	0	1 (8.3%)	0	0	0
E	4	0	0	0	0	4 (100%)	0	0	0	0
F	7	0	0	0	0	0	7 (100%)	0	0	0
G	2	0	0	0	0	0	0	2 (100%)	0	0
H	4	0	0	0	0	0	0	0	4 (100%)	0
I	2	0	0	0	0	0	0	0	0	2 (100%)

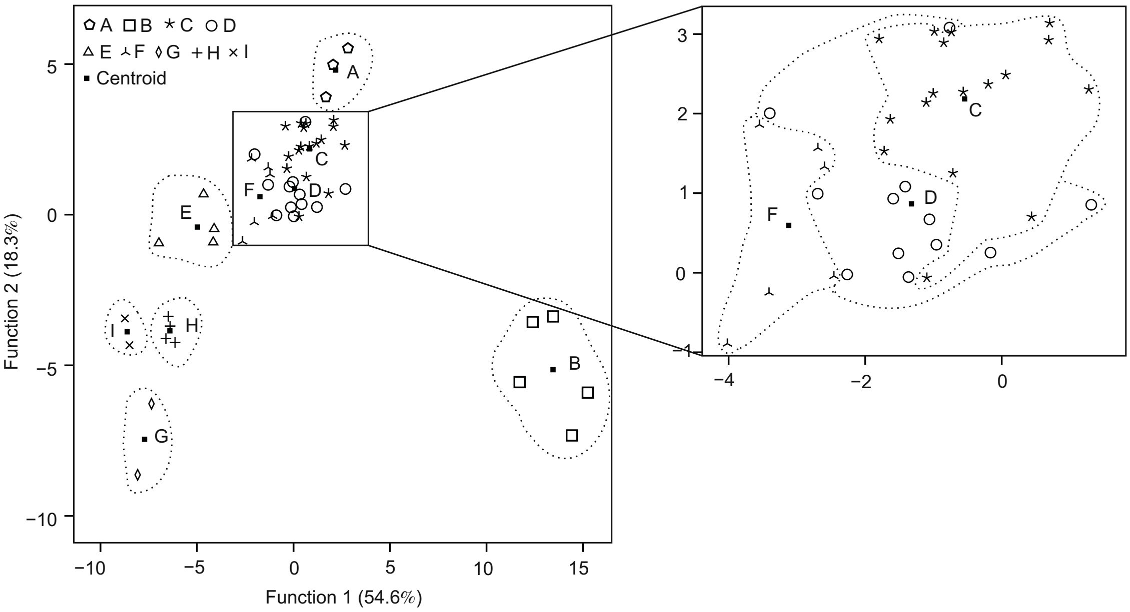

Figure 4 The predicted groups plotted against discriminate functions 1 and 2 for the topsoil samples of the Yili Basin (see Table 1 for vegetation types Groups A–I).

meadow. High contents of *Artemisia*, Chenopodiaceae and Poaceae characterized these pollen assemblages. The pollen content of *Artemisia* approximately doubled that of Chenopodiaceae. A valley breeze that brings *Artemisia* pollen from low to high altitudes most likely causes the high content of *Artemisia* pollen. The montane steppe flourishes along the south slope of the Tianshan Mountains from 2100 to 2800 m a.s.l. This area contains more Poaceae pollen (18.9%) content and less *Artemisia* pollen (17.8%) content than the Yili Basin [15]. The different altitudes and climates between the Yili Basin and the south slope of the Tianshan Mountains produce the differences in the modern pollen assemblages from the montane steppe.

The constructive plants in the desert steppe include *Stipa*, *Seriphidium transiliense* and *Kochia prostrate*. The vegetation coverage and pollen taxa reduce in the desert steppe. *Artemisia* and Chenopodiaceae dominated the pollen assemblages, whereas the Poaceae pollen content dropped below 6%. The pollen assemblages from the desert steppe in the Yili Basin were similar to those of east China, which indicates an overrepresentation of *Artemisia* and Chenopodiaceae pollen an underrepresentation of Poaceae pollen [28,30,32,33]. However, the pollen assemblages from the desert steppe clearly differ between the Yili Basin and the south slope of Tianshan Mountains. The latter contains more *Ephedra* pollen, which indicates a drier environment [15].

Seriphidium transiliense and *Kochia prostrate* dominated the plants in the *Artemisia* desert. *Artemisia* pollen comprised more than 60% of the assemblages, whereas Chenopodiaceae pollen comprised less than 30%. The constructive plants in the Chenopodiaceae desert include *Chenopodium glaucum*, *Ceratocarpus arenarius* and *Seriphidium*. The Chenopodiaceae pollen content exceeded 65%, whereas *Artemisia* pollen content comprised no more than 25%, and the presence of other pollen taxa was low. The pollen assemblages from the *Populus euphratica* forest contained higher content of *Artemisia*, Chenopodiaceae and *Hippophae* with few *Typha*; however, no *Populus* pollen was found, which indicates that this pollen does not reflect its parent plant coverage [12]. Thin exine wall, low sporopollenin content and consequent rapid oxidization, and a lack of distinguishing features all contributed to the low rate of *Populus* pollen in the pollen assemblages [34].

The floodplain meadows were primarily distributed in low-altitude areas and depressions of mountain dominated by *Phragmites*, *Typha* and *Tamarix* communities. The *Phragmites* community contained more Poaceae pollen (25.9%) than the subalpine meadow and montane steppe zones. *Typha* communities are characterized by high content of *Typha* (19.2%) and *Rumex* (9.4%) pollen that represent the proportions of their parent plants well. The presence of *Tamarix* pollen was low (0.7%) in the *Tamarix* community, which indicates that *Tamarix* pollen does not represent its parent plant well [30]. *Ulmus* pollen (7.7%) content was high in the *Tamarix* community; these results are correlated with the growth of *Ulmus* in the river valley.

4.2 A/C ratios and their climatic significance

Artemisia and Chenopodiaceae pollen are most important components of the modern pollen assemblages in the Yili Basin. *Artemisia* and Chenopodiaceae plants were primarily distributed in the low-altitude desert, whereas the montane steppe, subalpine meadow and Cupressaceae shrub zones contained few or no *Artemisia* or Chenopodiaceae plants.

However, *Artemisia* and Chenopodiaceae pollen comprised more than 55% of the shrubs, meadow and steppe, which suggests that these pollen types are overrepresented. In general, both types represent the ecology of the region, but they do not indicate their parent plants well [13,30]. The percentages of *Artemisia* and Chenopodiaceae pollen decreased as altitude increased in the Yili Basin. Nevertheless, the pollen content of *Artemisia* or Chenopodiaceae exceeded 30% in the high-altitude Cupressaceae shrubs due to their high rates of pollen production and the valley breeze in the basin.

EL-Moslimany [35] suggested that the A/C ratio is an index of dryness given that greater Chenopodiaceae percentages appear in desert regions, whereas higher *Artemisia* percentages characterize more steppe-like environments. Later work found that the A/C ratios obtained from different vegetation types effectively indicated moisture in arid and semiarid regions in Asia [13,28,33,35–39]. In general, A/C ratios fall below 0.5% in deserts, from 0.5 to 1.2 in desert steppes, and above 1 in steppes in Xinjiang [40]. These ratios sufficiently indicate moisture levels when the sum of *Artemisia* and Chenopodiaceae pollens are above 50% [40]. Because the A/C ratios were below 50% in the *Picea schrenkiana* forest, we did not discuss the A/C ratios specific to that zone.

The A/C ratios ranged from 0.1 to 5 among the 56 surface pollen samples in the Yili Basin. The minimum ratio was recorded from the Chenopodiaceae desert, whereas the maximum was recorded from the montane steppe (Figure 5). Large fluctuations exist in the A/C ratios within same vegetation types; for example, the ratios in subalpine meadow and montane steppe zoned ranged from 0.4 to 3.1 and from 0.8 to 5, respectively. The A/C ratios from the Chenopodiaceae desert were less than 0.5 but greater than 0.5 in all the others. The A/C ratios were greater than 1.2 in the wet subalpine meadow and montane steppe zones. The A/C ratios were between 1 and 1.2 in the relatively dry Cupressaceae shrub, desert steppe, *Populus euphratica* forest and floodplain meadow zones; however, these ratios rose to 2.5 in the dry *Artemisia* desert. When the *Artemisia* desert was ignored, the A/C ratios increased with altitude, peaked in the montane steppe and subalpine meadow zones located in the middle mountain region, then decreased (Figure 5). The A/C ratios effectively indicate the vertical moisture changes in the Yili Basin.

Certain studies have shown that human activities can influence A/C ratios; for example, the steppe degradation caused by overgrazing increases the number of Chenopodiaceae plants, which decreases the A/C ratios [33,41]. The modern pollen data from the Yili Basin also revealed the effect of human activities on the A/C ratios; for example, the ratios were below 0.5 in two samples from the subalpine meadow collected at the primary pastoral area of the Kazakhs. In addition, the plant taxa are homogenous in the *Artemisia* desert, which is dominated by *Seriphidium transiliense*. This plant produces large amounts of pollen, thereby resulting in higher A/C ratios (mean 2.5). Although the habitat of *Artemisia* desert is wetter than the Chenopodiaceae desert, it is drier than the subalpine meadow and montane steppe. Therefore, caution should be used when interpreting the A/C ratios is used to recover the paleoclimate, given the high ratios obtained from the *Artemisia* desert.

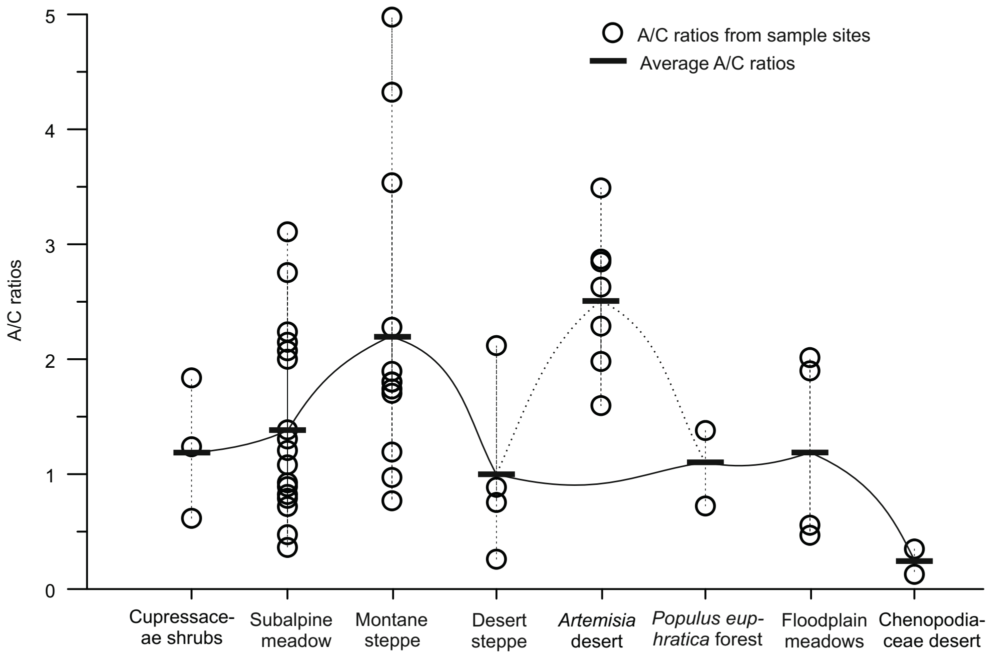

Figure 5 A/C ratios from different vegetation types in the Yili Basin.

5 Conclusions

This study investigated nine vegetation zones: Cupressaceae shrubs, *Picea schrenkiana* forest, subalpine meadow, montane steppe, desert steppe, *Artemisia* desert, *Populus euphratica* forest, floodplain meadow and Chenopodiaceae desert. Twelve pollen taxa (*Picea*, Cupressaceae, *Ulmus*, *Artemisia*, Chenopodiaceae, Poaceae, Asteraceae, *Taraxacum*, *Arenaria*, Cannabaceae, *Hippophae* and *Typha*) are most abundant in the Yili Basin and can be used as the significant taxa for paleoclimate reconstruction in this area. *Artemisia*, Chenopodiaceae, *Picea* and Poaceae are the most important taxa among these twelve.

Different vegetation types can be discriminated by applying qualitative and quantitative methods to the pollen assemblages. We confirmed the presence of Cupressaceae shrubs and *Picea* forest close to the pollen collection site when the pollen percentages were greater than 1% and 5%, respectively. *Artemisia*-Chenopodiaceae-Poaceae-*Picea*-Asteraceae-*Taraxacum*-*Arenaria* pollen assemblages revealed the growth of subalpine meadow. *Artemisia*-Chenopodiaceae-Poaceae-Cannabaceae pollen assemblages characterized the montane steppe. The desert steppe contained large amounts of *Artemisia* and Chenopodiaceae pollen contents. The *Populus euphratica* forest contained large amounts of *Artemisia*, Chenopodiaceae and *Hippophae* pollens. *Artemisia* comprised over 60% of the pollen content in the *Artemisia* desert, whereas Chenopodiaceae comprised over 65% of the pollen content in the Chenopodiaceae desert. *Typha* and *Rumex* pollen dominated the *Typha* community.

A/C ratios can effectively indicate vertical moisture changes in the Yili Basin. These ratios were below 0.5 in the dry Chenopodiaceae desert zone and ranged from 1 to 1.2 in the relative dry Cupressaceae shrub, desert steppe, *Populus euphratica* forest and floodplain meadow zones. The ratios were greater than 1.2 in the humid subalpine meadow and montane steppe zones. A/C ratios can climb up to 2.5 in the dry *Artemisia* desert. A combination of A/C ratios and pollen assemblages is necessary to accurately reconstruct paleovegetation and paleoclimate.

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