(Short Communication)

An Attempt to Subdivide Fossil *Pediastrum* from Lake Kopais, Southeast Greece

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Further identification of fossil *Pediastrum* (green algae) from the late Quaternary at Lake Kopais, Southeast Greece is attempted. Ecological studies have indicated that the abundance of *Pediastrum* in the Mediterranean region could be a useful indicator of high lake level (more than ca. 2m depth), but the *Pediastrum* in the Kopais data is abundant both in the Holocene and the last glacial, indicating no significant lake level change through the last deglaciation. On the contrary, our attempt of *Pediastrum* subdivision reveals that the majority of *Pediastrum* in the last glacial consisted of *P. kawraiskyi*-type. The ecological data have pointed out that this type prefers low water temperature (less than ca. 23℃ in summer), and thus the abundance of *P. kawraiskyi*-type in cold periods does not necessarily indicate the high lake level at that time. The resulting low values of the other *Pediastrum* in the last glacial deserve attention. Coupled with our pollen data showing significantly drier last-glacial conditions around the lake, the low values of *Pediastrum* except *P. kawraiskyi*-type may indicate relatively lower water level of Lake Kopais in the last glacial. Our results strongly suggest that non-lake-level indicators such as *P. kawraiskyi* need to be excluded from the total *Pediastrum* spectra for the reliable lake level reconstruction based on the *Pediastrum* evidence.

Key words : Greece, the last glacial, lake level, *Pediastrum*, pollen

Lake level records are quite useful geological data for the reconstruction of past moisture conditions particularly in arid to semi-arid regions [1-3]. In the Mediterranean region, however, the apparent discrepancy between the reconstructed moisture conditions based on geomorphology and palynology has been pointed out. Paleoshoreline records, provided mainly by geomorphological evidence, have reconstructed significantly higher lake level at the last glacial than in the Holocene [4-8]. On the other hand, all the available pollen data in the Mediterranean region has reconstructed remarkable *Artemisia* steppe that suggests semi-arid glacial conditions [9-14]. The present annual mean precipitation in the Mediterranean region is 400 - 500mm or more [15], while that of *Artemisia* steppe zones is ca. 150-300 mm [16, 17]. This means that the last glacial conditions in the Mediterranean region reconstructed by

pollen evidence is significantly drier than today. It has been argued that the high lake level in the last glacial may be explained by the low evaporation level resulted from the low temperature at that time [18]. According to this argument, the high lake level in the last glacial does not necessarily indicate the higher precipitation level at that time. An alternative explanation for this discrepancy has been proposed by assuming larger seasonal variation of rainfall in the last glacial than today. According to the water balance model by Prentice *et al.* [19], high lake level coincides with dry, open vegetation around the lake if most of the rain falls in winter and flows into the lake without being consumed by the surrounding vegetation. However, no distinct geological evidence to verify these hypotheses has been reported.

Fossil *Pediastrum* could also indicate the past lake level. In the Mediterranean region, ecological studies have shown that the *Pediastrum* abundance could be a useful indicator of open water conditions with higher water depths of more than 2m [20]. The advantage of this alga is that it is automatically extracted by the standard pollen preparation process because the physical and chemical characters of *Pediastrum* resemble those of pollen. This means that the lake level history as well as the past moisture conditions around the lake could be reconstructed by a single pollen data set with *Pediastrum* spectra. The problem is that the validity of this approach has not yet been accepted as widely as that of geomorphological techniques. Since *Pediastrum* is a highly diversified algal group, all the *Pediastrum* species does not necessarily show similar environmental preferences. A typical example of the exception is *Pediastrum kawraiskyi*. Ecological studies have shown that the distribution of this species is determined by water temperature rather than water depths. That is, *Pediastrum kawraiskyi* prefers low water temperature (less than 23°C in summer) rather than high water depths [21]. For reliable lake level reconstruction, therefore, such a non-lake-level indicator needs to be excluded from the total *Pediastrum* spectra.

In this paper, we provide *Pediastrum* spectra as well as a pollen data with AMS ^{14}C ages from Lake Kopais, Southeast Greece. Lake Kopais is one of the largest poljas (karstic depression) in Greece that are located in coastal lowlands (ca. 100m above sea level). Although it has been drained artificially, its original length was as much as 20km [22]. In 1984, a 120m core was recovered about 2 km off the end of the depression. The sediments basically consist of white or greenish-gray lake marl, showing high carbonate contents often exceeding 90%. Microscopic observation has shown that the highly calcareous character of Kopais sediments is attributed to numerous clay-sized carbonate particles. Absence of specific structures on these particles indicates that they are most probably precipitated origin. Detailed pollen results at Lake Kopais have been described in another paper [23]. In this paper, we show a selected pollen diagram on the top 16.2m part of the 120m core (Fig. 1). A significant vegetation change through the last deglaciation is observed in our pollen diagram. The Holocene is characterised by dense forest of *Quercus* while the last glacial is characterised by open steppe of *Artemisia* and Chenopodiaceae. This results agree with other available pollen data in the Mediterranean region, strongly suggesting the moister conditions in the Holocene and the drier conditions in the last glacial. On the other hand, the curve of total *Pediastrum* does not show any significant value changes through the same time interval. Although a high peak of *Pediastrum* is recognised near the end of the last glacial, the total *Pediastrum* is more or less abundant throughout the diagram. It is unlikely that no lake level change occurred through the last deglaciation because our pollen spectra show a drastic moisture change around the lake. The most probable explanation for this disagreement is that the total *Pediastrum* is a heterogeneous mixture of lake-level indicators and non-lake-level indicators such as *P. kawraiskyi*. For practical lake level reconstruction, therefore, the total *Pediastrum* needs to be subdivided.
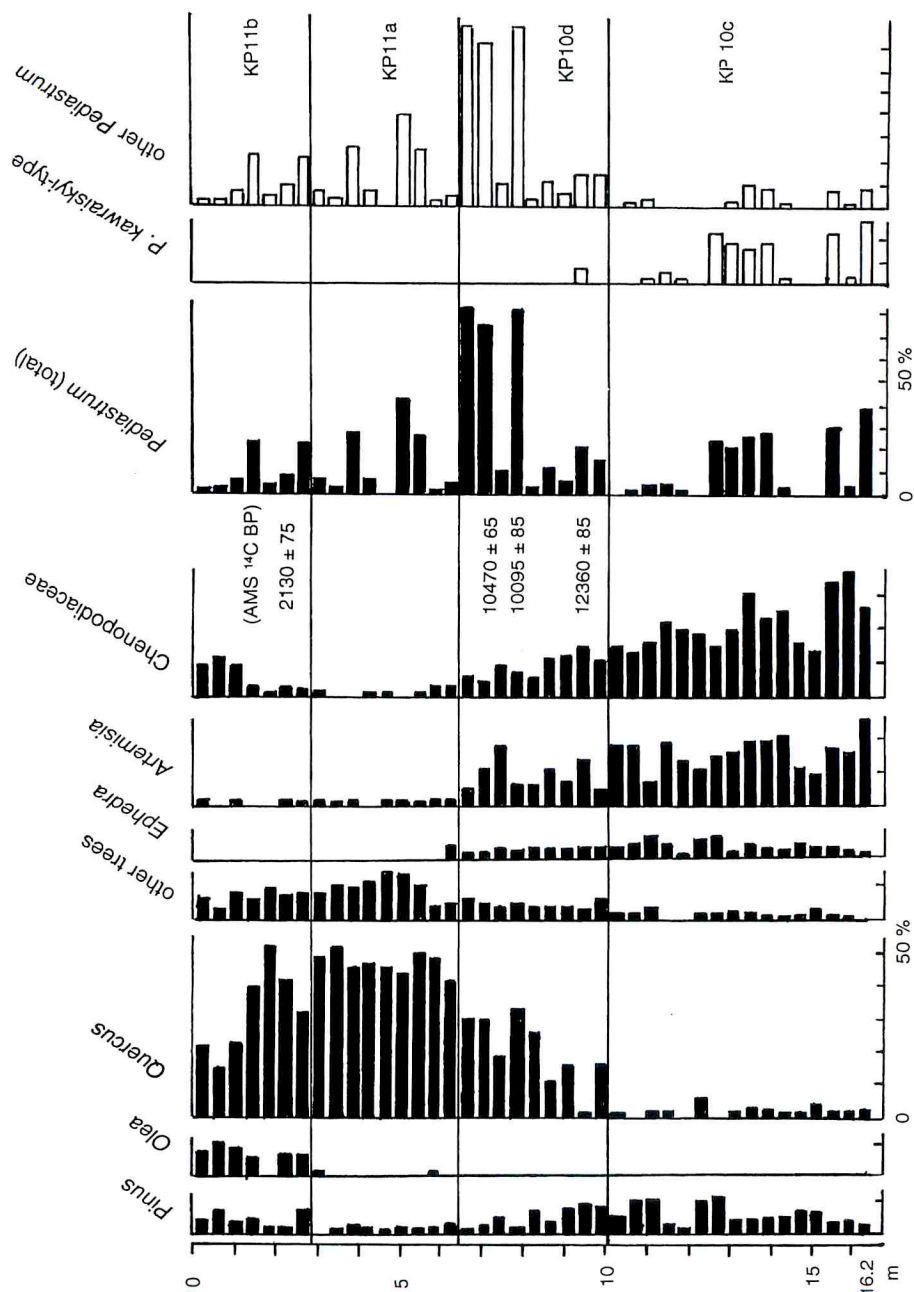
Fig. 1. Selected pollen diagram with *Pediastrum* spectra on the top 16.2 m part of a 120 m core from Lake Kopais, Southeast Greece. The lab numbers of AMS ^{14}C ages are GrA 6238, 6239, 6240 and 6241 in descending order. Pollen of trees and herbs excluding aquatics is used as a total sum to calculate the percentage of individual pollen taxon. Similarly, every pollen taxon, spore and *Pediastrum* itself are used as a sum to calculate the percentage of *Pediastrum*.

We attempted to differentiate *P. kawraiskyi* from other *Pediastrum* and showed it as *P. kawraiskyi* -*type*. This type is defined morphologically by triangular peripheral cells, visible openings between the body cells and the remarkable verrucate pattern [23]. The results of our attempt were successful. Most of the *Pediastrum* that had been abundant in the last glacial was identified as *P. kawraiskyi*-type, while by the end of the last glacial this type disappeared and was completely replaced by the other *Pediastrum*. This is consistent with the cold-loving character of *P. kawraiskyi*. It should be noted that the exclusion of *P. kawraiskyi*-type resulted in the clearer value change of the other *Pediastrum*. That is, the curve of the other *Pediastrum* shows low values during the last glacial, while it shows significantly high values near the end of the last glacial and in the major part of the Holocene. It declines again in the mid - to late Holocene. The possible explanation of this decline might be attributed to the extremely 'salty' lakewater conditions in the mid - to late Holocene that allowed almost pure carbonate deposition in 1.0 - 5.8m depths of the core.

Conclusively, our attempt to differentiate *P. kawraiskyi*-type revealed that the value of the other *Pediastrum* was significantly lower in the last glacial than in the end of the last glacial to the Holocene. It is hardly possible to attribute this low value of the other *Pediastrum* to the low water temperature in the last glacial because Lake Ioannina, an inland site in northern Greece, has provided significantly abundant fossil *Pediastrum* except *P. kawraiskyi*-type despite its significantly colder climate than that of Kopais [24]. The low value of the other *Pediastrum* may reflect the low lake level in the last glacial. Our pollen data, which have suggested significantly drier conditions around Lake Kopais in the last glacial, support the above discussion. We emphasize that it is often indispensable to exclude non-lake-level indicators such as *P. kawraiskyi* from the total *Pediastrum* spectra for reliable lake level reconstruction based on the *Pediastrum* evidence.

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ギリシャ南東部のコパイ湖から産出した
Pediastrum 化石の細分の結果について

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　ギリシャ南東部に位置するコパイ湖から産出した第四紀末期の *Pediastrum*（緑藻類）化石について，詳細な同定を試みた．生態学的な調査によれば地中海地域における *Pediastrum* の産出は水深 2 m 以上の高水位の有力な指標をなりうるが，コパイ湖において *Pediastrum* は最終氷期にもまた後氷期にも多産しており，この記録から最終氷期と後氷期の湖水位の変動を読みとることはできない．一方，この *Pediastrum* に対してさらに同定をすすめた結果，コパイ湖において最終氷期に産出する *Pediastrum* の大多数は *P. kawraiskyi* 型に属することが明らかとなった．生態学的資料によると，この型は水位に関係なく夏の気温が約 23℃ 以下の低水温を好むことがわかっている．したがって，この種が多産することはかならずしも当時の湖が高水位であったことを意味しない．一方それ以外の *Pediastrum* が氷期に顕著に少なかったことは，最終氷期の花粉記録がコパイ湖周辺の顕著な乾燥状態を示していることを考慮に入れると，おそらく氷期にコパイ湖の水位が低かったことの反映と考えることができる．本研究の結果は，*Pediastrum* を用いて湖水位の復元を行うためには *P. kawraiskyi* 型のような非湖水位指標種を省く必要があることを示している．