



# Palynological record from a composite core through Late Cretaceous–early Paleocene deposits in the Songliao Basin, Northeast China and its biostratigraphic implications

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## ABSTRACT

Two boreholes drilled approximately 75 km apart in the Songliao Basin, Northeast China, have together provided a composite core that represents an almost continuous section through Late Cretaceous–early Paleocene deposits. Eight biozones have been established for this succession of seven formations based on occurrences and associations of biostratigraphically significant palynomorph genera. Seven of these suggest that there was more or less continuous deposition from the late Turonian to the early Paleocene, with the eighth encompassing a Miocene formation that overlies the succession unconformably. This zonation provides a new chronostratigraphic framework for the Late Cretaceous deposits of the Songliao Basin. The ages of most of the formations involved differ from those determined previously. One of the sedimentary units, the Mingshui Formation, includes the Cretaceous/Paleogene boundary, which seems to be indicated by an apparent “mass extinction” of palynomorph taxa, a comparatively rare occurrence outside North America. The upper Quantou Formation, the lowest unit in the succession, is dated as late Turonian–Coniacian, which is much younger than previously thought. The same applies to the overlying Qingshankou and Yaojia formations, and also to the other three (Nenjiang, Sifangtai and Mingshui) but to a lesser extent, in the conformable succession. The Early/Late Cretaceous boundary must now be located probably below the Quantou Formation, either between it and the underlying Dengloulou Formation or within the latter.

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## 1. Introduction

The sedimentary succession in the Songliao Basin of Northeast China (Fig. 1) has been regarded by many geologists (e.g., Gu, 1962, 1982a,b; BGMHRP, 1993) as including the most representative non-marine Cretaceous sequence in China. As a result, its sedimentological characteristics and fossil content have been much studied. Nevertheless, the age determinations of many of the formations involved have been, and continue to be, disputed (Table 1). Among the problematic issues are the locations of the major boundaries. The basal unit, the Huoshiling Formation, is considered to be Jurassic by some (e.g., Gu, 1982a, b; BGMHRP, 1993) and Early Cretaceous by others (e.g., Sha, 2007). The boundary between the Lower and Upper Cretaceous varies from the base of the Sifangtai Formation (Gu, 1962) downwards via the bases of the Nenjiang (RIEDDPAB, 1976,

83 pp.; Gu, 1982a, b) and Qingshankou (e.g., Yu et al., 1983; Liu, 1990; BGMHRP, 1993; Gao et al., 1999; Sha, 2007) formations to the Quantou Formation (e.g., Chen, 1983, 2000), the base of the Qingshankou Formation being the most popular at present.

These markedly conflicting opinions have depended to large extent on interpretations of the fossil groups upon which authors have relied. Specialists on ostracods and spinicaudatans (conchostracans), which are common throughout the Cretaceous succession in the Songliao Basin, have regarded their biotas as being strongly endemic, rendering correlations with other faunas difficult (e.g., Ye et al., 2002; Kong et al., 2006).

Palynology has played an important role in the subdivision of the succession, the earliest widely accepted zonation of the Cretaceous deposits being based mainly on spores and pollen grains (RIEDDPAB, 1976). The same is now true for the currently more popular interpretation of BGMHRP (1993). The evolutionary history of angiosperm pollen in the basin was considered by some palynologists to compare favourably with that known from other parts of the world (Gao, 1982; Gao et al., 1999). However, Li (2001) cast

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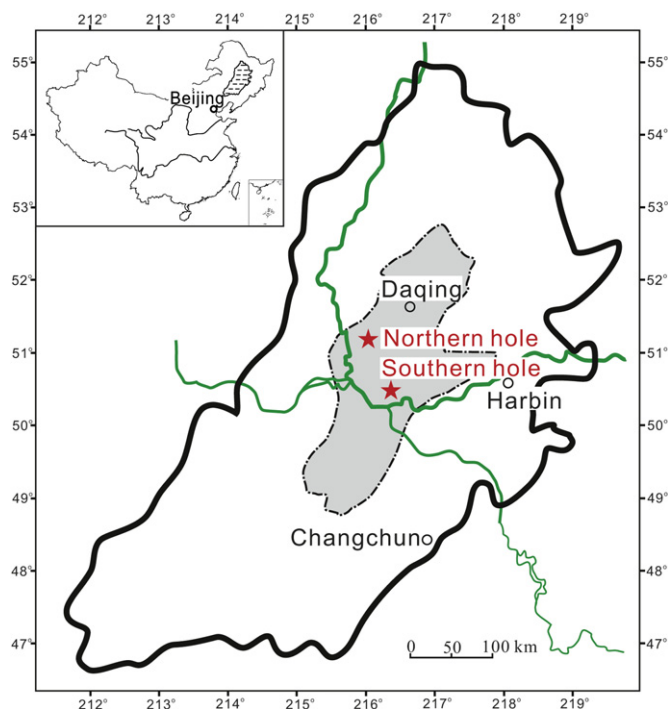


Fig. 1. Maps showing the location of the SK-1 boreholes in the Songliao Basin, North-east China, which were drilled in the depositional centre (shaded area) of the basin.

doubt on this interpretation. In his study of the spores and pollen grains in the Quantou Formation that were recovered from a well in the basin, he found that the angiosperm palynofloras differed from those noted previously by, for example, Gao et al. (1999) in containing *Cranwellia* and *Lythraites*. These indicate a very much younger age for the Quantou Formation than has been generally accepted. The problem with Li's study is that it was based on only one core sample, with no palynological data from under- or overlying deposits.

Another difficulty is that the Cretaceous deposits in the Songliao Basin are poorly exposed. Definitions of some of the formations (e.g., the Qingshankou Formation) are based solely on subsurface data from wells that have been drilled in the area. In 2007 the National Basic Research Program of China (2006CB701400) conducted a whole-core programme in the basin, which led to the recovery of a composite core that represents almost all of the Upper Cretaceous succession. This was obtained from two boreholes (Fig. 1) that have been referred to as a single well (SK-1) even though they were drilled about 75 km apart. Recovery was nearly 100 per cent: 99.73% for the southern borehole, 94.56% from that in the north, thus providing an excellent opportunity to record changes in the palynological content of a more or less continuous sedimentary succession that reflects deposition for most of the Late Cretaceous and early Paleocene. The resulting biozonation, which also takes into account overlying Miocene beds, is presented in this paper. Its significance in the context of previous age determinations in the Songliao Basin and its correlation with zonations of successions elsewhere is also considered.

## 2. Lithological succession

The two boreholes of this drilling programme, which, as noted above, have been collectively referred to in the literature as the SK-1 well hitherto, both encountered an oil-shale near the base of the second member of the Nenjiang Formation. This is a significant stratigraphic marker and provides an accurate basis for tying

together the two core sections recovered. The boreholes penetrated a succession from the Mingshui Formation near the top down through the Sifangtai, Nenjiang, Yaojia and Qingshankou formations to the Quantou Formation at the base. The uppermost part of the section consists of the Neogene Taikang Formation, which overlies the Minguishi Formation unconformably. A brief account of the lithology of these units in stratigraphic order from oldest to youngest is given below. Detailed descriptions can be found in papers by Cheng et al. (2009), Gao et al. (2009), Wang et al. (2009a,b).

The Quantou Formation in the Songliao Basin comprises red to green sandstones, sandy conglomerates and mudstones. It is subdivided into four members, but only the upper two, i.e., the Third and Fourth, were penetrated. These were encountered in the southern borehole from 1915.0 to 1782.9 m (i.e., through 132.1 m of section) and mainly comprise greenish-grey to brown mudstones and siltstones. Most of the samples are palynologically barren, but a few yielded quite large assemblages of fairly well-preserved spores and pollen grains.

The Qingshankou Formation consists of black to grey mudstones with thin interbeds of marl. It was also encountered in the southern borehole from 1782.9 to 1285.9 m (a thickness of 497.0 m). Spores and pollen grains are abundant in this formation, but usually poorly preserved.

Reddish-brown, greenish-grey and greyish-white rocks make up most of the Yaojia Formation with mudstones and siltstones the dominant lithologies, but there are also subordinate pale grey, brown and pink sandstones and a few black mudstone interbeds. They were encountered in the southern borehole from 1285.9 to 1128.2 m, i.e., through 157.7 m of section. Some beds proved to contain abundant spores and pollen but many were barren.

The Nenjiang Formation is dominated by dark-grey to black mudstones and siltstones. Pale grey sandstones occur sporadically through the succession, becoming more common towards the top along with frequent red and green mudstones and siltstones. Most of the succession was recovered from the northern borehole at depths ranging from the bottom of the hole at 1783.16 m up to 1021.6 m, a thickness of 761.56 m. Only the basal part was penetrated by the southern borehole at depths 1128.2–955.0 m. The oil-shale marker bed mentioned above, which provides a reliable basis for correlating the two cores, occurs at 1780 m in the northern section and at 1020 m in that recovered from the southern borehole. Pollen and spores are abundant and fairly well preserved in the formation.

The Sifangtai Formation is a colourful unit. Reddish and greenish mudstones and siltstones dominate but pale grey sandstones also occur and pale grey conglomerates are occasionally encountered. This formation was logged from 1021.6 to 807.12 m in the northern borehole, i.e., through 214.48 m of section. Palynological recovery was generally poor, but spores and pollen grains were extracted in abundance from several horizons, and most of these are well preserved.

The Mingshui Formation is also a colourful unit but consists of coarser sediments overall, pale grey to yellowish-grey sandstones being as common as the varicoloured (pink to red, reddish-brown and greenish-grey) mudstones and siltstones. It is present from 807.12 to 210.57 m in the northern borehole, a considerable thickness of 596.55 m. The section above 343.4 m is more weakly consolidated and has a greater mud to silt content than the lower part, with grey siltstones and mudstones dominating the succession. As a result, this part of section, which may include eroded and redeposited younger Miocene deposits, is only questionably assigned to the formation (pollen and spores recovered from a sample at 233.4 m indicate a Miocene age: cf. below). Much of the formation has not been conducive to the preservation of palynomorphs, but fairly common

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