

## **Fern spikes and global events - Impact related?**

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**Abstract.** In the K-T boundary layer of many profiles worldwide there is an increase in the ratio of fern spores to angiosperm pollen (called fern spike). The question is: What determined this change in floral assemblages? Interestingly this fern spike appears directly above an iridium-rich clay layer. So, it suggests itself that maybe the event that caused the iridium anomaly has something to do with the temporary increase of fern spores.

### **Mass extinction at the K-T boundary**

It is well known that the turn from the Mesozoic to Cenozoic Era 65 Ma ago is marked by a mass extinction. There is agreement that the end of Mesozoic Era was signaled by a worldwide extinction of marine floras and faunas. A lot of species did not manage the change. So it was the end for ammonoids, belemnites, inocerami; on land dinosaurs became extinct. But it is not so obvious for the terrestrial floral. For that there are different reasons. It is hard to find a continuous terrestrial sedimentary sequence with the necessary fossil record. Because plants give the base of terrestrial food chain and that is one of the reasons why macrofossils are difficult to recover from sediments. But microfossils like palynomorphs can help a lot to discover changes in climate and devastation up to extinction events. A continuous marine sedimentary sequence of K-T boundary exists in eastern

Hokkaido (Japan) based of planctonic foraminifera. A 6-10 cm thick layer of pyrite-rich, fossil-poor, greyish-black claystone marks the boundary and it is similar to the boundary clay well known from Europe. In this claystone of the Japanese profile framboidal pyrite abounds and concentration of iron is five times more concentrated than in siltstones below and above (Saito, Yamanoi & Kaiho, 1986). In the following the changes in terrestrial sedimentation and the florals of the latest Cretaceous interval will be discussed.

#### **The western interior of North America - Raton Basin**

Wolfe & Upchurch (1986) analyzed a section of latest Cretaceous of the Western Interior of North America. There vegetation from palaeolatitude 40° to > 56° N was dominantly broad-leaved evergreen. In the south there was dry open-canopy forest. This is shown by small leaf size, paucity of drip tips and thick cuticles with cutinized hairs on both surfaces. Up to 1 cm below the K-T boundary there are no indications for significant change in climate. But assemblages less than 3 m above the boundary (phase 2 and 3, see table 1) show “ecological disruption and mass kill”. (Wolfe & Upchurch, 1986)

Table 1. Wolfe & Upchurch, Jr (1986)

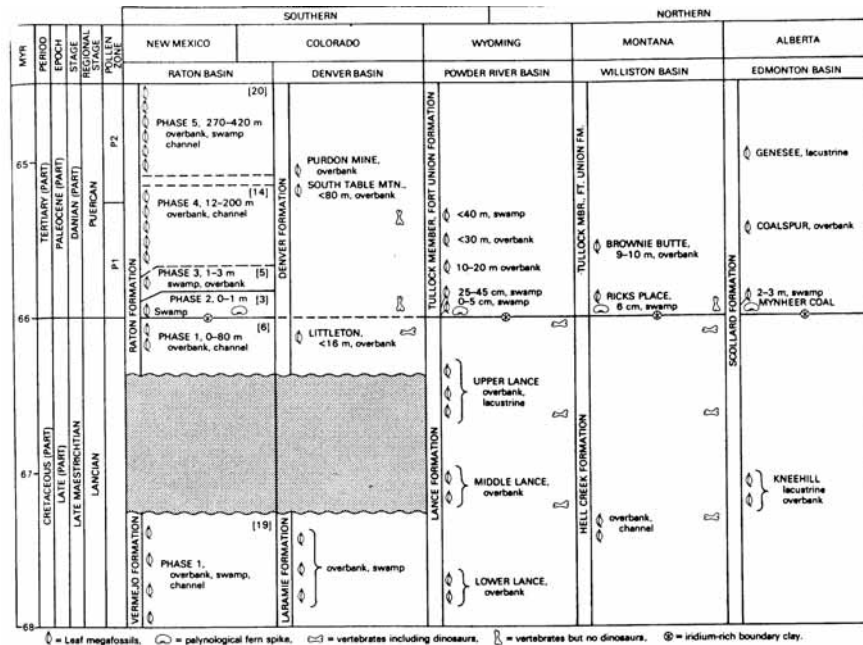


Fig. 2 Stratigraphical and depositional occurrences of some plant megafossil assemblages relative to the Cretaceous-Tertiary boundary in the western interior. Estimates of absolute ages are based on some radiometric and some palaeomagnetic data<sup>34,35</sup>; Palynological data from refs 5, 36-38; stratigraphical data from refs 16, 39 and unpublished data; Physiognomic and floristic data from refs 16, 40-44 and unpublished data. Following some floral symbols are measured or estimated stratigraphical interval from the boundary. Numbers in brackets in the Raton Basin column are numbers of individual localities.

Phase 2 is represented by the palynological fern spike. The sequence is dominated by herbaceous monocots and/or ferns which reach into phase 3. Here floral diversity is low that makes it hard to presume temperature. But there must have been a change which is shown by the fern spike, low diversity and the iridium rich layer. This boundary clay and the fern spike exist not only in the sequence of Raton Basin but also in Powder River Basin (Wyoming), Williston Basin (Montana) and Edmonton Basin (Alberta). (Wolfe & Upchurch, 1986)

**The boreal Far East**

After Saito et al. (1986) the Hokkaido section contains palynofloras which offer the opportunity to compare changes in terrestrial floras directly with

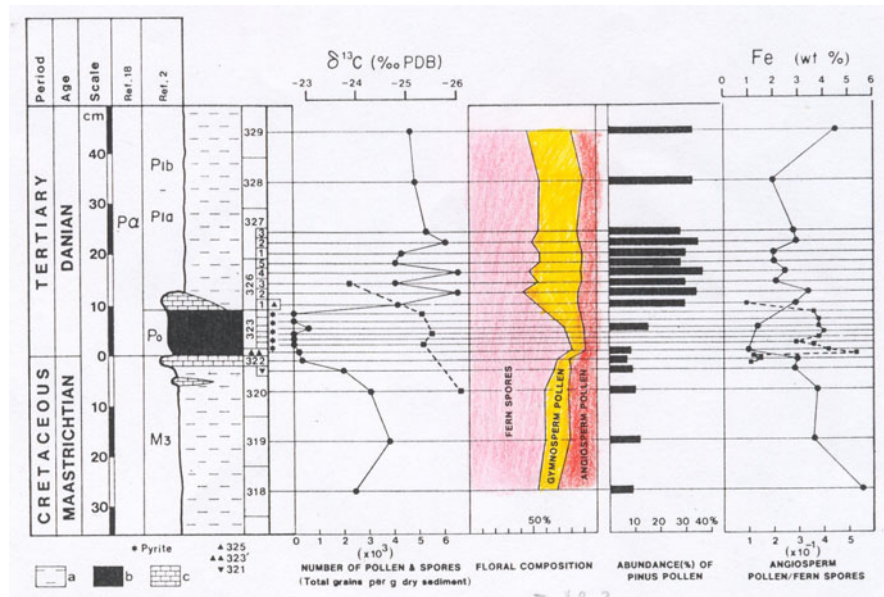
the known marine extinction event. The section is characterized by three palynomorph assemblages:

1. Fern-angiosperm-rich florals of the latest Cretaceous
2. palynomorph assemblages, dominated by fern spores in the boundary claystone
3. pine-dominated gymnosperm pollen in the earliest Tertiary

In the boundary claystone angiosperm and gymnosperm pollen abundances decline while fern spores increase. The same phenomenon is known from the western interior of North America (Wolfe & Upchurch, 1986).

The dominance of fern spores ends a few centimeters above the boundary layer. But in contrast to the Cretaceous flora the Paleocene assemblages show a increase content of *Pinus* pollen (see table 2 ).

**Table 2.** Saito et al. (1986)



So, after this, a global change is obvious. But some questions remain. What caused the iridium-rich boundary clay and why is there such a high increase of fern spores? Was it one event that caused both?

### **Floral changes at the K-T boundary - A “June Impact Winter”?**

Wolfe (1991) set up the theory of a June Impact Winter for the K-T boundary caused by a, so the author, “large bolid impact”. Since in the oceans thermal buffering has an effect he put his eye on terrestrial environments. Aquatic leaves in the boundary section near Teapot dome (Wyoming) show deformation that seems to be produced by freezing.

The Teapot Dome site was a lily pond characterized by very low sedimentation rates. In fine-grained sediments there were found thousand of leaves. After Wolfe (1991) the plants died suddenly: roots are fragmented, roots and rhizomes were pulled off the bottom. The fragments do not occur in the original growth position, an indication for high-energy transport by rapid water flow but this is contrary to the obvious fine grained sediment. So it seems to be that after a time of decay the plants were covered by fine-grained debris. Wolfe (1991) dated back this time of deceasing for June and there are some interesting facts which provide this idea.

The fossils found in the boundary sequence include immature and matured pollen. This means that the plants were still flowering. So, killing must have started during growing season. The leaves or better their cuticles show irregular folds that are interpreted by Wolfe (1991) as made by freezing.

What caused this unexpected freezing in summer? It could have been a large bolid impact. This supposition is confirmed by different points which

will be discussed later on. So, if there was a large impact, dust would have been sent out into the atmosphere and the result would have been darkness and thereby coldness. After this impact winter aerosol resting in the atmosphere absorbs infrared rays that is forcing the greenhouse-effect. So after a cold period a hot one is following.

But there are some authors who do not agree with Wolfe. Hickey supposes that there was an impact but climate change was much slower than in Wolfe's scenario. He also thinks, that Wolfe (1991) did not have enough material of fossils to substantiate his thoughts.

However, it seems to be for certain that there was a force that brought extinction.

### **Signs for an impact event**

The discussion about an impact event at the K-T boundary started in the 80ies. In 1981 in a profile near Gubbio (Italy) a sequence with an iridium-anomaly was found (Alvarez, 1990). This anomaly of iridium content also exists in the boundary-clay of Raton Basin, Powder River Basin, Williston Basin and Edmonton Basin in North America and in the Hokkaido section as well as in many other localities worldwide. In eastern Hokkaido the K-T Boundary contains a "6-10 cm thick layer of pyrite-rich, fossil-poor, grayish-black claystone" (Saito et al., 1986). Iridium on earth is very rare but in meteorites it is pretty abundant. So, after the impact an explosion set free dust with high concentration of iridium into the atmosphere. It is dispersed there and after a while it is deposited and build a layer in sediments. For this amount of iridium-rich layers worldwide there must have been a meteorite with a size of about 10 km (based on the fact that it was a meteorite with common composition) (Stanley).

Beside this anomaly in the same level were found microtektites and micro-

scopically small diamonds. This indicates high pressure that could be generated by an impact (Alvarez W. et al., 1995).

One of the best indications for an impact was found in the Gulf of Mexico in front of Yucatan (Alvarez, 1995). There is a round structure, called Chixulub-impact-structure, located with a dimension of 200 km. In the middle of the structure is a hole of approximately 100 km of diameter. For this effect the meteorite must have a size of maybe 10 km. Stones, made up of the melting effected by the heat during the large impact, indicate a age of 65+/- 0.4 Ma (after dating with Ka-Ar-method) (Stanley). That is the time when the end of Mesozoic Era is set. The Chixulub-impact-structure is asymmetric. This demonstrate that the assumedly meteorite came from the southeast and adopted under an angle of 20 to 30° (Alvarez W., 1997). Consequently the dust spread to the northwest and caused because of its heat a large wildfire in the west of North America. Fossil record attests to this setting: in west of North America nearly 75% of floral species became extinct while in New Zealand and Australia not so many species were affected . Otherwise layers of soot found in the K-T layers in Denmark, Spain and New Zealand also indicate a large wildfire determined by a large impact (Saito et al., 1986).

### **Fern spike**

In all this boundary sequences it is demonstrative that after the iridium anomaly follows a layer contending a high rate of fern spores ( they reach 80-90% of palynomorph assemblages). It is of interest that this kind fern spike not only exist in layers of the K-T-boundary. It is also known from the Permian-Triassic-boundary which is as well marked by a mass extinction (Looy et al., 2001).

Ferns are opportunists (Benton & Harper, Basic palaeontology). If there is no possibility for other plants to grow ferns will take the chance and settle the landscape. Thus, the fern spike could confirm the impact theory. In recent times it was studied that ferns were the first growing plants after a volcanic eruption or a wildfire. But what advantage do they have related to other plants? They do not need too much time for growing, are well ecologically adapted and they reproduce quickly. But their success on burned and devastated land do not take too long. They cannot prevail against the other plants that start after a while to recapture the territory. "Higher" plants take place then and make use of by ferns prepared earth. This fact fits to the notice that the fern spike is only a temporary phenomenon.

## **Conclusion**

So, there are many reasons for a relation between the fern spike and an impact:

1. Worldwide iridium-rich boundary clay
2. The structure near Yucatan, interpreted as caused by an impact
3. Microtectites and microscopically small diamonds in the boundary layer reporting high pressure
4. A layer of soot
5. Fossil-poor horizon

The fern spike alone is no argument for an impact, but it tells us that any force devastated earth at the change from the Mesozoic to Cenozoic Era, so that many species became extinct and only opportunists like ferns were able to use the situation for their profit.

But seeing the unusual accumulation of fern spores in sediments with the background of other unusual phenomena in the K-T boundary layer, the

impact theory explains pretty good the obvious changes in environment after the Cretaceous.

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