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AN IRIIDIUM RICH LAYER AT THE CRETACEOUS/TERTIARY BOUNDARY  
IN THE BIDART SECTION (SOUTHERN FRANCE).

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**Abstract.** We have measured an anomalous iridium concentration in the clays of the Cretaceous/Tertiary boundary in the Bidart section, thus confirming the planetary character of this anomaly. The iridium anomaly is synchronous with a very sharp minimum of the  $^{13}\text{C}/^{12}\text{C}$  ratio and there is no evidence of any other iridium enrichment in marly concentrations away from the boundary. The integrated iridium content is of the same order of magnitude as that calculated from deep sea cores in the Pacific Ocean. In spite of a careful search, we have found no evidence of any exotic material.

# Introduction

In 1979, an iridium-rich layer was discovered by Alvarez et al. (1979) in the clays of the Cretaceous/Tertiary boundary of the Gubbio section. Because iridium is a very rare element of the earth's crust, this discovery has led to a series of speculations about its origin and to a number of scenarios of catastrophes aiming to account for the dramatic changes in the biosphere observed at this boundary.

Since this first result, the iridium-rich layer has been found at the Cretaceous/Tertiary boundary in many additional sections widely distributed on the earth. Alvarez et al. (1982) show a world map with 36 Cretaceous/Tertiary boundary localities with iridium anomalies. This wide geographical distribution clearly indicates that the existence of the iridium-rich layer is a planetary phenomenon.

The first investigation of the Bidart section, however, failed to detect the iridium-rich layer, at least within the sensitivity of the experimental apparatus which was 12 ppb (Smit and Ten Kate, 1982). As part of a detailed investigation of all the sedimentary and geochemical properties of this section (a preliminary report of which can be found in Delacotte, 1982), a careful search was made to determine whether the Bidart section could constitute an exception to the planetary distribution of iridium at the Cretaceous/Tertiary boundary.

## Geological Setting, Stratigraphy, Lithology and Clay Mineralogy

The section appears as a fully exposed outcrop along the Bidart beach a few kilometers south of Biarritz.

From a lithological point of view, the studied portion of the section is composed of three different units: the Maastrichtian calcareous marly beds, the boundary layer clay and the Danian hard and pink limestones. The clay layer (samples 331 to 343) is about 15 cm thick, with a colour varying gradually from green at the base to ochre-brown at the top. Its contact with the underlying Maastrichtian beds is relatively abrupt, while a gradual transition is observed into the overlying unit. The Maastrichtian unit is interrupted by a fault 8 m below the Cretaceous/Tertiary boundary, and the Danian unit by a gully, beyond which precise stratigraphic correlation is difficult. The calcareous-rich marls and the pink limestones correspond to wackestone-mudstone units with pelagic foraminifera quite similar to the microfossils observed at Gubbio.

Bio-magnetostratigraphic analyses are rather complicated because of redeposition phenomena and weathering of the magnetic minerals near the Cretaceous/Tertiary boundary. The Maastrichtian part of the section studied in this work (up to sample 32 CB) corresponds to the *M. prinsii* nanoplankton biozone. Pelagic foraminifera studies did not detect the principal marker, *A. mayaroensis*, but the foraminiferal association corresponds to this zone. The magnetostratigraphic results indicate that little sediment accumulated during the Late Maastrichtian. The first clay samples (331 and 332) are characterized by a marked scarcity of coccoliths and planktonic foraminifera and can be distinguished from the underlying samples only because of the greater density of *Thoracosphaera*. Sample 333 contains some large size benthic foraminifera associated with rare and poorly preserved *Heterohelix* sp., some *Globotruncanella petalloides* and some *Planorotalites eugubinus* and *P. aff. eugubinus*. *G. eugubina* appears very early in the boundary clay, in agreement with Smit (personal communication), who has found some very rare but very well preserved individuals of this type 0.4 cm above the base of the clay layer. In the Danian part of the section, the three successive Tertiary foraminifera and nanoplankton biozones are present, but also several indications of concentrations or hiatus (hardgrounds, samples 45 and 48 for example).

The Cretaceous/Tertiary boundary, as determined by biostratigraphic analysis, thus coincides with the lithological boundary and is located at the base of sample 331 (Figure 1). Moreover, it has already been shown by Renard et al. (1982) that the  $^{13}\text{C}/^{12}\text{C}$  ratio on total rock is characterized by a sharp minimum at this precise

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TABLE 1. Abundances of iridium.

<sup>a</sup> sample	<sup>b</sup> h cm	<sup>c</sup> CaCO <sub>3</sub> %	weight mg	<sup>d</sup> Ir±σ ppb
73 bulk	>3 m	60	80.5	0.3±0.3
72 bulk	>3 m	82	153.0	0.1±0.4
66 bulk	>3 m	66	154.3	0.1±0.5
63 bulk	>3 m	69	175.6	0.4±0.6
62 bulk	>3 m	87	99.8	0.1±0.6
48 bulk	220	78	84.1	0.8±1.3
" i.r.	"	-	75.0	1.0±1.7
45 bulk	160	85	79.5	1.0±0.8
" i.r.	"	-	87.3	0.7±5.2
341 bulk	6 to 8	50	116.4	1.1±0.9
333 bulk	4	26	110.7	1.8±1.3
332 bulk	2 to 3	16	99.0	4.7±1.2
" i.r.	"	-	82.0	7.0±2.8
331 bulk	0 to 2	5	109.4	6.3±1.1
" i.r.	"	-	123.7	5.3±1.6
32CB bulk	-0.5	66	99.4	0.5±1.0
" i.r.	"	-	65.6	2.2±1.2
32CA bulk	-1	84	88.6	0.8±1.2
" i.r.	"	-	83.8	2.9±1.8
32B bulk	-5 to -2	62	49.5	0.5±0.5
		7	130.6	4.2±0.6
<sup>a</sup> Bidart		"	107.5	5.9±0.5
		-1 to 4	140.4	4.9±0.5
Standard		"	85.7	4.7±1.2
		"	60.3	5.4±0.7
Mean				5.0±0.6

<sup>a</sup>Samples from the Bidart section in the Cretaceous/Tertiary boundary clay layer (32CA to 341) and in several marly beds away the boundary.

<sup>b</sup>"h" represents the distance above or below the boundary layer. >3m means samples recovered in the Danian unit, with no possible precise stratigraphic correlation with the boundary clay layer.

<sup>c</sup>Carbonate contents have been measured with EDAX microprobe on powdered dried sample pastilles. Measurements on acid-insoluble residues are noted "i.r.".

<sup>d</sup>Iridium abundances are given with the standard deviation.

<sup>e</sup>Results for "Bidart Standard" were obtained from different irradiations on bulk samples.

stratigraphic horizon. Thus this ratio appears as a fine marker of the Cretaceous/Tertiary boundary.

From a mineralogical point of view, no particular anomaly has been found at the Cretaceous/Tertiary boundary, except for lower carbonate fraction. The relative abundances of the different minerals are the same as in the underlying and overlying levels (micas, illite, kaolinite and chlorite). In the same way, in addition to the calcareous biogenic tests (benthic foraminifera), only detrital quartz and rare feldspars have been observed, in spite of very careful sediment manipulations to search for spheroids similar to those observed by us in Stevn's Klint section or by other groups in Cretaceous/Tertia-

ry boundary sediments from different localities (Smit and Klaver, 1981, Kyte and Rasmussen, 1982, Montanari et al., 1983). Energy-dispersive X-ray analysis of the carbonate free fraction indicates the same relative abundances of major elements in the clay layer as in levels above or under the Cretaceous/Tertiary boundary. In summary, no evidence of any exotic material has been observed in this locality.

#### Iridium Measurements: Experimental Methods and Results

##### Experimental Methods

Iridium abundances were determined by instrumental neutron activation. The samples were irradiated at the Centre d'Etudes Nucléaire de Saclay, through the Pierre Sue Laboratory, using the OSIRIS reactor. This reactor produces a large neutron flux (1 to 2.3 10<sup>14</sup> n/cm<sup>2</sup> .s) containing about 10% epithermal neutrons, providing favorable conditions for the analysis of Ir 191 (37% of natural iridium).

Samples were selected from different levels in the Cretaceous/Tertiary boundary clay (7 samples) and also from other stratigraphic horizons away from it, in beds of marly concentrations (7 samples). In all these samples, the irradiation and subsequent analyses were performed on bulk sediments, without any chemical treatment. In addition, for 6 "twin" samples, irradiation and analysis were performed on the carbonate-free fraction obtained after leaching with acetic acid. We have also analyzed several aliquot parts of an internal standard specimen ("Bidart Standard") obtained by thoroughly mixing 110 g of clays from the Cretaceous/Tertiary boundary layer.

Monitoring was obtained using different USGS rock standards (W-1 or MAG-1) and also an iridium standard constituted by an aluminium barrel with 5 ppm iridium content, prepared by A.A. Samadi.

Radioactive counting has been done about two months after irradiation, using either a GeLi detector (volume 105 cm<sup>3</sup>, resolution 2.5 keV) or an intrinsic Ge detector (volume 85 cm<sup>3</sup>, resolution 1.75 keV) for periods of 15 to 65 hours, except for the "carbonate-free" sample (45) which was counted for two hours only.

##### Results

1) In the Cretaceous/Tertiary boundary samples of the Bidart section, all the analyses indicate the presence of an iridium-rich layer, as shown in Table 1 and Figure 1. The planetary character of the iridium-rich layer is thus not refuted by this study. Moreover, the maximum iridium concentration of 6 ppb, although much lower than the value of up to 60 ppb reported in Denmark by Alvarez et al. (1980), is of the same order of magnitude as the concentrations reported from the Cretaceous/Tertiary boundary layer of other sections which range from 0.8 to 44 ppb (Alvarez et al, 1982 and references herein).

2) Other samples, from marly concentrations situated away from the Cretaceous/Tertiary boundary, have also been carefully examined to

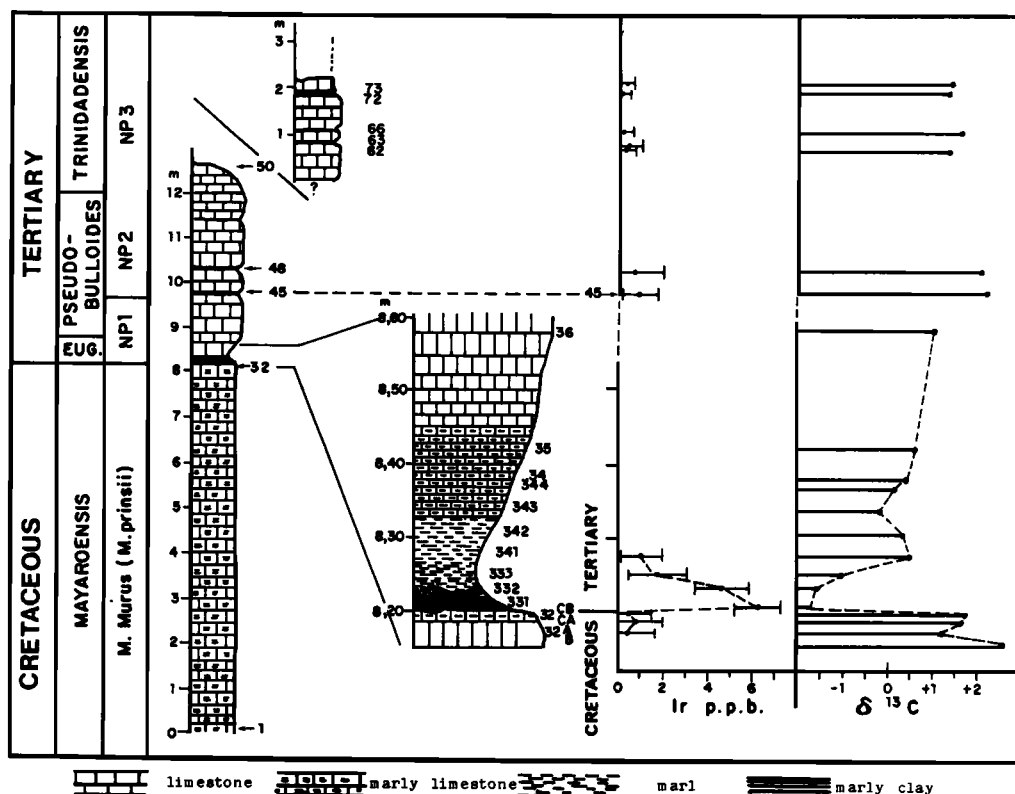


Fig. 1. Stratigraphic section at Bidart and comparison of iridium abundances with delta  $^{13}\text{C}$  of total carbonate.

detect any iridium anomaly. To achieve a better sensitivity, some of these measurements were made on carbonate-free fractions. As shown in Table 1, no significant iridium content was detected in these samples. Because this negative result could arise from large iridium leaching during the chemical treatment (up to 55% iridium leaching has been reported by Alvarez et al. (1980)), this point was directly checked in samples where bulk and carbonate-free measurements were possible and statistically significant. These include several aliquots of the "Bidart Standard" which has been specifically prepared for this study, and some samples from the boundary clays. All the measurements yield identical iridium content when referenced to the carbonate-free fraction showing that the chemical treatment used does not induce any iridium loss. Systematic measurements on the "Bidart Standard" show that iridium leaching occurs in these clays only in cases of very strong chemical treatment (8 N hydrochloric acid). Thus, we are quite confident that there is no evidence in these marly concentrations of the Bidart section of any iridium-rich layers away from the Cretaceous/Tertiary boundary, such as those reported by Wezel et al. (1981) in the Gubbio section (numerous levels with iridium content up to 11.6 ppb for bulk samples in levels clearly outside the Cretaceous/Tertiary boundary). For samples close to the boundary clays, the low iridium content has not yet allowed a more precise measurement of the shape and width of the iridium distribution.

3) An evaluation has been made of the total amount of iridium accumulated at Bidart on a

1 cm<sup>2</sup> column over the transition. Measurements in sediments of the boundary clays yield a mean density of 1.5 g of dry sediment per cubic centimeter of in situ sediment. Assuming this value as a correct average for all the sediments, we obtain a minimum integrated iridium content of about 35 ng/cm<sup>2</sup> over a 14 cm high sedimentary column. Thus, this section appears similar to other nearby Spanish sections (Zumaya: 70 ppb and San Sebastian: 53 ppb (Alvarez et al., 1982)). These values are comparable with the 80 ng/cm<sup>2</sup> calculated by Kyte and Wasson (1982), which can be considered as the best planetary mean estimate since it was obtained from results in one of the oceanic areas with the slowest and most regular sedimentation rate.

#### Conclusion

The exceptional and planetary character of the iridium anomaly is thus confirmed at Bidart. The iridium anomaly is synchronous with a minimum of the  $^{13}\text{C}/^{12}\text{C}$  ratio, so that both phenomena appear as a specific characteristic of the Cretaceous/Tertiary boundary sediments. However, our measurements do not allow to know the precise peak shape and width, in particular the distance from the Cretaceous/Tertiary boundary at which the iridium content lowers again to its normal crustal value. Furthermore, the most frequently proposed hypothesis, impact of a 10 km-diameter meteorite, implies in the iridium-rich levels the existence of ejecta for which we found no evidence in this section.

Finally, we consider that in spite of abundant data obtained by the scientific community

in the last five years, the origin of the Cretaceous/Tertiary ecological event needs further investigation.

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