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A SEARCH FOR IRIDIUM IN THE DECCAN TRAPS AND INTER-TRAPS

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Abstract. It has been suggested that flood basalts in the Deccan (India) might be associated with events at the Cretaceous-Tertiary boundary (KTB). A search for iridium in 47 samples from lava flows and inter-trap sediments in the Deccan yields negative results. Concentrations are not statistically different from zero, with a minimum detection level on the order of 0.1 ng.g^{-1} (ppb). This does not help to constrain the debate on the internal vs external origin of KTB boundary events, since for instance Ir could have been outgassed from the magma, and original concentrations of only 0.05 ng.g^{-1} prior to outgassing are sufficient to account for the worldwide Ir excess mass at the KTB.

Introduction

The discovery of anomalous concentrations of iridium (Ir) in the clay layer which marks the Cretaceous-Tertiary boundary (KTB) in many localities led to the suggestion that meteorite or cometary impacts may have been responsible for the many exceptional events (both biological and geochemical) which are recorded at that boundary (Alvarez et al, 1980; for a recent review see Alvarez, 1986). An alternate hypothesis argues for a primary internal, volcanic cause (e.g. McLean, 1983; Officer and Drake, 1985; Courtillot and Cisowski, 1987; Hallam, 1987). In particular, Courtillot et al (1986) have presented combined paleomagnetic, paleontological and radiochronological evidence that the extensive flood basalts in Deccan (India) may have been erupted in a comparatively short time interval of order 1 Myr or less, apparently at KTB time. Recent $^{40}\text{Ar}/^{39}\text{Ar}$ dating (Duncan and Pyle, 1988; Féraud et al, 1988; Courtillot et al, 1988), confirms that most of the Deccan volcanism occurred between 66 and 68 Myr and the volcanic hypothesis must clearly be considered seriously (e.g. Courtillot and Cisowski, 1987; Hallam, 1987). Paleomagnetism (Courtillot et al, 1986) and stable isotopes (Margolis et al, 1987) are still the strongest evidence that volcanism may actually have occurred in a few short pulses, with the largest event occurring in less than 10^5 yr at the KTB (Courtillot, 1988).

Of the many geochemical signatures associated with the KTB, Ir remains the most popular one. The way in which it could be produced in gigantic volcanic events remains to be studied. Luck and Turekian (1983) point out that the $^{187}\text{Os}/^{186}\text{Os}$ ratios which they measure in KTB sections

could be a volcanic imprint with a mantle origin (though they favour the meteoritic interpretation); also, Olmez et al (1986) have measured significant Ir concentrations in volatile emissions from the Kilauea volcano (for eruptions probably far smaller than what must have occurred in the Deccan).

Sampling

In view of the differing interpretations of sources of Ir at the KTB and possible connection of the Deccan traps with this event, we have analysed iridium concentrations in approximately 40 samples coming both from individual lava flows and from some of the rare occurrences of sediments interlayered between the flows (the so-called "inter-traps"; e.g. Sahni et al, 1984). While doing field-work in India, we happen to have had access to a preprint reporting significant Ir concentrations in the famous Takli intertrap in Nagpur (e.g. Sahni et al, 1982, 1984). These results apparently never appeared, but prompted us to undertake further sampling for Ir measurements.

The basaltic samples (Figure 1) include 2 from the lower and upper flows in Dongargaon (DK 01-02B and 02.07B

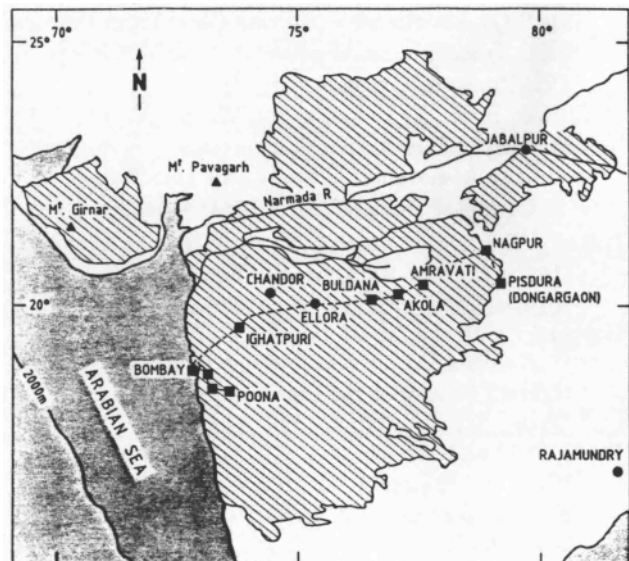


Fig. 1. Present outcrops of Deccan basalts (ruled) and sites sampled for iridium analysis (squares). Some additional localities are given for convenience (circles). See also Courtillot et al (1986, 1988).

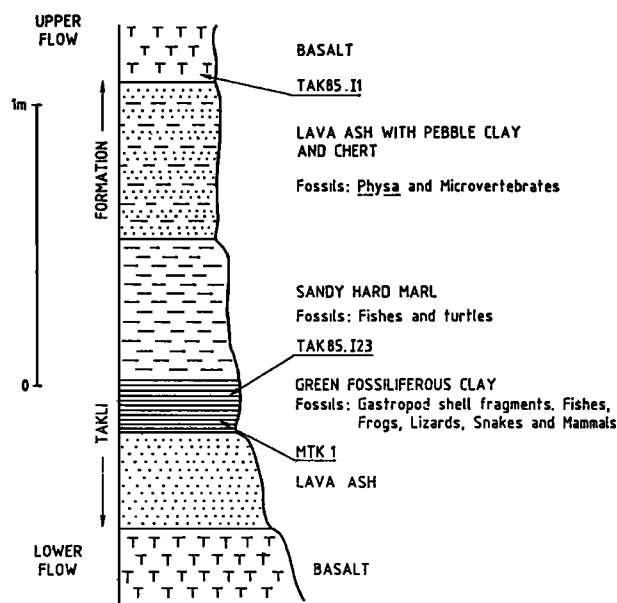


Fig. 2. Stratigraphic section of the Takli type section, where sampled for iridium analyses (Takli Police Line in Nagpur; after Sahni et al, 1984). Location of three samples is indicated. Samples are listed in Table 1 and are regularly spaced by 5 cm.

respectively), one from a flow on the road from Dongargaon to Nagpur (AP 1026), 2 from the lower and upper flows at Takli in Nagpur (DK 11-01 and 04-02A respectively), samples on the road from Nagpur to Bombay (AP 1031 from Kondhali, 43 km from Nagpur; AP 1032 85 km from Nagpur; AP 1034 from Akola, 265 km from Nagpur; and AP 1044, 1047 to 1049, 1052, 1053, 1055 from a sequence of flows near Ighatpury). Finally, a trachyte intruding basalts near Bombay was also sampled (AP 1062; for locations and lava flow codes see also Table 1 in Courtilot et al, 1986).

The inter-trap samples include a detailed section from the Takli inter-trap between the two main Nagpur flows (Sahni et al, 1982, 1984). The total thickness of the intertrap is 1.2m (Figure 2) and has been dated as the youngest Maestrichtian outcrop, which still contains dinosaur remains (Prasad et al, 1986; Vianey-Liaud et al, 1987). The intertrap and the flows above and below are all reversely magnetized (Courtilot et al, 1986; Vandamme et al, in preparation). 24 samples were taken every 5 cm in these lava ashes, sandy hard marl and greenish clays (TAK 85-11 to 122, MTK1). Also, 2 samples, a sandy clay and a red clay (MP1 and MP2), were taken respectively .5 and 1 m below the bottom flow at Pisdura (near Dongargaon, Fig 1). Nearby, in Dongargaon, 1 sample (MD 1) was taken in a limestone underlying the lowermost flow, and 4 samples (MD 2 to MD 5) in beige to green clays which form an inter-trap.

Analysis

Iridium is the easiest element that can be analysed in the platinumoid series. Our samples were not subjected to any phase separation or chemical treatment. They were simply heated and ground, then weighed and sealed in quartz vials. They were then subjected to neutron irradiation for several hours in the Osiris reactor at the Pierre Sûre laboratory (CEN, Saclay); the neutron flux is $2.10^{18} \text{ m}^{-2} \text{ s}^{-1}$ ($2.10^{14} \text{ cm}^{-2} \text{ s}^{-1}$ in usual cgs units). After neutron activation, we detected the coincidence of the 316 keV and 468 keV γ -ray lines emitted during disintegration of ^{192}Ir , using a 2D spectrometer. This technique allows for a secure

TABLE 1a. Results of iridium analyses in the Deccan inter-traps. Sample locations are shown in the figures and specified in the text.

Sample code	Ir content ng/g	Accuracy ng/g
TAK-85-1-1	0.080	0.102
TAK-85-1-2	-0.003	0.174
TAK-85-1-3	0.015	0.026
TAK-85-1-4	-0.078	0.133
TAK-85-1-5	-0.045	0.043
TAK-85-1-6	0.071	0.164
TAK-85-1-7	0.013	0.198
TAK-85-1-8	-0.085	0.125
TAK-85-1-9	-0.114	0.332
TAK-85-1-10	-0.073	0.061
TAK-85-1-11	0.039	0.069
TAK-85-1-12	0.070	0.232
TAK-85-1-13	-0.050	0.189
TAK-85-1-13B	-0.044	0.110
TAK-85-1-14	-0.182	0.150
TAK-85-1-15	0.004	0.045
TAK-85-1-16	-0.180	0.128
TAK-85-1-17	0.131	0.060
TAK-85-1-18	-0.029	0.164
TAK-85-1-19	-0.008	0.077
TAK-85-1-20	0.188	0.160
TAK-85-1-21	-0.132	0.162
TAK-85-1-22	-0.168	0.101
MTK1	0.007	0.033
MD1	-0.080	0.200
MD2	0.060	0.152
MD3	-0.112	0.217
MD4	-0.058	0.120
MD5	0.125	0.110
MP1	0.240	0.190
MP2	0.012	0.035

identification of iridium by eliminating any possible interference with other elements, and provides an excellent sensitivity; the minimum detection level ranges from 0.04 to 0.3 ng.g^{-1} (or ppb; Table 1). The method is discussed more fully by Rocchia et al (1984, 1987).

TABLE 1.b. Results of iridium analyses in the Deccan traps. Same locations are shown in the figures and specified in the text.

Sample code	Ir content ng/g	Accuracy ng/g
DK-01-02B	0.084	0.056
DK-02-07A	-0.096	0.206
AP-1026	-0.050	0.071
DK-11-01	-0.243	0.228
DK-04-02A	-0.021	0.233
AP-1031	-0.019	0.262
AP-1032	0.078	0.229
AP-1034	-0.306	0.325
AP-1055	0.056	0.169
AP-1053	-0.200	0.200
AP-1052	0.364	0.381
AP-1049	-0.316	0.192
AP-1048	0.036	0.083
AP-1047	-0.429	0.306
AP-1044	0.021	0.089
AP-1062	-0.018	0.043

Results

Results are listed in Table 1. The conclusion is quick and simple: nowhere did we find significant Ir concentrations in the 47 samples analysed. The concentration is in most cases less than the minimum detection level, and is negative about half of the time, which indicates very low values below the noise level. Assuming that the 16 basalt samples are derived from a homogeneous population with normal distribution, we find a mean concentration of -0.005 ng.g^{-1} , an error on the mean of 0.025 ng.g^{-1} and a χ^2 value of 12.1 for 15 degrees of freedom. Similarly, the 24 Takli intertrap results provide a mean of $-0.005 \pm 0.015 \text{ ng.g}^{-1}$ ($\chi^2 = 18.3$ for 23 degrees of freedom). These values are similar to those usually found for sediments, either marine or continental, in "normal" conditions, i.e. outside the KTB sections or away from hardgrounds (Rocchia et al, 1986). They are significantly smaller than the concentrations which we have measured in lava samples from some hotspot volcanoes, such as Piton de la Fournaise in Reunion Island, or Kilauea in Hawaii ($0.25 \pm 0.03 \text{ ng.g}^{-1}$; Rocchia et al, unpublished data, 1988).

Discussion

The negative result reported in this paper unfortunately does not help us in constraining the solution of the debate between an internal and an external scenario for the KTB events. Although not many flows have been analysed, the remarkable homogeneity of the results would suggest a unique source for the lavas. Some might say that the lack of measurable iridium in the Deccan lavas and intertraps argues against any link with the source of the KTB events. However, should one follow the idea that the Deccan represents the appearance at the surface of the Earth of the Reunion hotspot (Courtilot et al, 1986; Courtilot and Besse, 1987), and accept that most of the Ir originally contained in the magma escaped in the form of volatile complexes such as fluorides during outgassing of the magma (Olmez et al, 1986), all that can be constrained is the original Ir concentration of that magma. For a total mass of $2.5 \cdot 10^8 \text{ kg}$ Ir (based on a reasonable value of the global iridium fluence of about 50 ng cm^{-2} , or $5 \cdot 10^{-7} \text{ kg m}^{-2}$; Kyte et al, 1985) and a total volume of $\sim 10^6 \text{ km}^3$ for the Deccan basalts, the original concentration is found to be on the order of 0.05 ng.g^{-1} (or $5 \cdot 10^{-11}$), i.e. about three times less than the present Reunion and Hawaii hotspots, and generally below the detection threshold in our technique (Table 1; see also calculations by Alvarez et al, 1980, and Officer et al, 1987). The key question, still unsolved, remains the total duration of the Ir signal in KTB sections (Officer and Drake, 1985; Rocchia et al, 1987; Courtilot and Cisowski, 1987; Courtilot, 1988). Further work should concentrate on the time signature of this iridium signal, particularly on the multiplicity of concentration peaks (e.g. Rocchia et al, 1987). The resolution and spacial extent of many published iridium profiles is not sufficient to ascertain whether there are other, secondary peaks, away in both space and time from the KTB, as has been observed for instance for stable isotopes and stepwise extinctions (e.g. Margolis et al, 1987; Hallam, 1987).

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