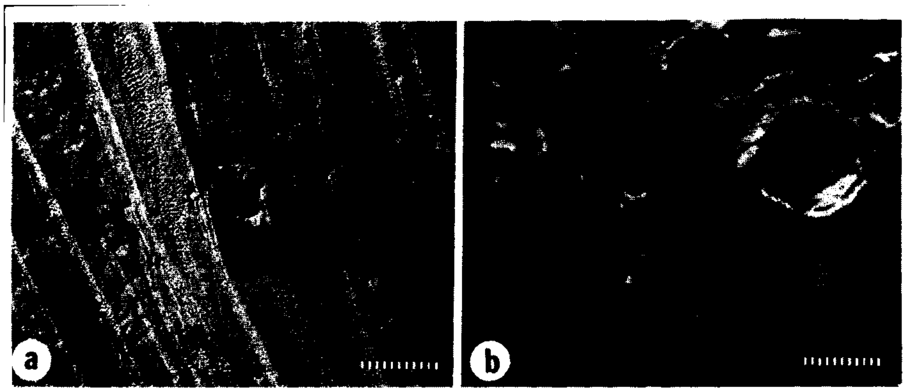

Fig. 2. (a) Landsat view of El-Baz Crater (scale bar, 5 km). (b) Viking Orbiter view of a crater in the Cerberus region of Mars with a dark patch on the leeward side (scale bar, 20 km).

Mars. Canyons and wind streaks revealed on Mars by Mariner 9, Viking 1, and Viking 2 resemble features in the Uweinat area photographed by the Apollo-Soyuz astronauts and Landsat (*5*).

The most imposing features of the Uweinat Desert are the linear dunes of the Great Sand Sea. This sand sea covers an area the size of Ireland—over 72,000 km^2. Individual dunes are often over 100 km long and 100 m high. The base of each dune, 2 km wide on the average, is usually a gently sloping, relatively stable whaleback dune. The whalebacks are commonly topped by sharp-crested, constantly shifting seif dunes.

Another significant feature of the Uweinat Desert is the abundance of crater forms. Most of these craters are believed to be of volcanic origin, such as the Clayton craters, a field of some 20 (*6*). Furthermore, four subdued circular features approximately 130 km east-southeast of Uweinat Mountain and up to 14 km in diameter were revealed by Landsat images. These features, named Bagnold, Miskin, Shaw, and Sweeting after the explorers whose tracks came nearest to them (*6*), have not yet been studied in detail and remain of unknown origin.

A circular feature was discovered among the dunes of the Great Sand Sea on Landsat multispectral scanner frame 10113-08135 and return beam vidicon frame 30960-07490 (site 1 in Fig. 1; Fig. 2a). It is located at 24.2°N, 26.4°E in sandstone of the Nubia series, which covers most of the southern part of the Western Desert. This crater is about 4 km in diameter, being 3.8 km across in one place and 4.2 km at the protrusion on the southeast corner. It has a complex structure with a flat floor, a terraced wall, a crenulated rim, and the subdued remains of an inner structure, approximately 1.6 km in diameter, that may have been a central uplift. The crater is surrounded by a rough-textured deposit, particularly on the east side. This deposit, which contains large blocks, extends up to 2 km from the rim.

The morphological characteristics of the crater are similar to those of craters produced by meteorite impact (*7*). Its outline is similar to that of the bowl-shaped (1.2 km in diameter) Barringer (Meteor) Crater in northern Arizona (*4*). However, the feature in the Western Desert may have formed by a circular diorite intrusion; after erosion by the wind only the hardened and metamorphosed sandstone would remain to form the circular crater (*8*).

Shadow measurements show that the crater is less than 100 m deep. However, because of its location in the path of sand-carrying winds, much of the original shape could have been modified. Also, the southwestern corner of its rim appears to have been eroded and partly buried by a sand dune (Fig. 2a). Because of the lack of named features in the crater's vicinity, I will use the prerogative of the discoverer and name it El-Baz Crater.

El-Baz Crater shows similarities to flat-floored craters in the lunar highlands and on Mercury. It shows even more similarities to martian craters because of its interaction with a strong wind regime in an arid environment. Of special significance are the protrusion on the crater's southeast corner and the crenulated rim, the deflection of dunes by the crater rim and the occurrence of a sand-free zone in its lee, and the dark splotch just south of the rim in the lee of the wind. All three features are common on martian craters (*5*), particularly in the Cerberus region (Fig. 2b). Because of this, an expedition will be organized to collect samples and to study the crater's morphology and interaction with the wind regime of the Great Sand Sea.

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Man-Made Radionuclides Confirm Rapid Burial of Kepone in James River Sediments

Abstract. *Profiles of man-made radionuclides in sediment cores from the James River estuary confirm the rapid burial of the pesticide Kepone. The greatest deposition of Kepone has occurred in zones characterized by very high sedimentation rates, 10 to 20 centimeters per year. Since sediment is the major Kepone reservoir, rapid burial probably reduces the exposure of organisms to further contamination. Disturbance caused by hurricanes or dredging, however, could return highly contaminated sediment to the surface although this sediment would be diluted with less contaminated particles.*

Estuaries are accumulation sites, at least in the short run, for many of the "lost" or discarded by-products of man's activities. Contaminants, such as heavy metals, radionuclides, or organic chemicals, which become associated with fine-grained sediment, are deposited in estuaries where river currents slacken and salinity-induced flocculation occurs. Simpson *et al.* (*1*) demonstrated that man-made radionuclides in the Hudson River estuary serve as useful indica-

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tors for both areas and rates of sediment accumulation. We have sought to apply similar methods to the James River estuary where sediments are contaminated with the chlorinated hydrocarbon pesticide Kepone (*2*). Kepone, like many other sparingly soluble contaminants, rapidly sorbed to suspended particulates and bottom sediments after entering the James River at Hopewell, Virginia. Since production (and hence release) of Kepone ended in 1975, the major reservoir of Kepone has been the sediment. The dynamics of this reservoir might be expected to control the rate of recovery of the aquatic and biotic reservoirs. The possibility that highly contaminated sediments from areas near the source will slowly be transported downstream raises concern over future increased contamination of the lower estuary.

Circulation in the James River estuary is partly mixed and the normal upstream limit of salt intrusion is near James Island (Fig. 1). Freshwater inflow averages 211 m^3/sec at Richmond, and erosion from the watershed produces 1.7×10^9 kg of suspended sediment per year (*2*). Sediment transport is quite irregular with major floods dominating the overall budget. Huggett *et al.* (*2*) estimated that 90 percent of the total sediment is delivered in only 11 percent of the time.

Table 1. Kepone production by year for 1966 through 1975 (*2*).

Year	Production (kg)
1966	35,935
1967	47,990
1968	36,535
1969	46,990
1970	41,460
1971	204,800
1972	176,970
1973	100,435
1974	457,630
1975	384,020

Neither the exact amounts of Kepone released to the aquatic environment nor the dates of release are known. Production of the compound began in 1966, peaked sharply in 1974, and terminated abruptly in 1975 (Table 1). Presumably, releases followed a similar historical pattern. Decomposition or desorption of Kepone from sediment is imperceptible (*2*). In contrast, the release history of man-made radionuclides from two sources is well known for the lower James River. Radionuclides from atmospheric fallout, such as ^{137}Cs, have been deposited in the watershed since the 1950's with the highest deposition occurring in 1963 (*3*). Relatively small amounts of ^{60}Co and ^{134}Cs, as well as ^{137}Cs, were introduced into the river in effluent from the Surry nuclear electric generating station located near the river. The most significant release was 14 Ci of ^{137}Cs in 1975.

We collected 24 box cores from the estuary in December 1978 (Fig. 1 shows the locations of 21 stations). Sections removed from several depths in the cores were subdivided for analyses: Kepone concentrations were determined at the Virginia Institute of Marine Science, and radionuclides at Oak Ridge National Laboratory. The analytical procedures and methods used have been described in (*2, 4*).

In cores from nine sites, Kepone and ^{137}Cs were not found deeper than 10 cm below the sediment-water interface, an indication of a lack of (or very low) net sediment deposition. The highest Kepone concentration found at such sites was 0.06 mg/kg at station D. Cores from 13 sites contained Kepone and radionu-

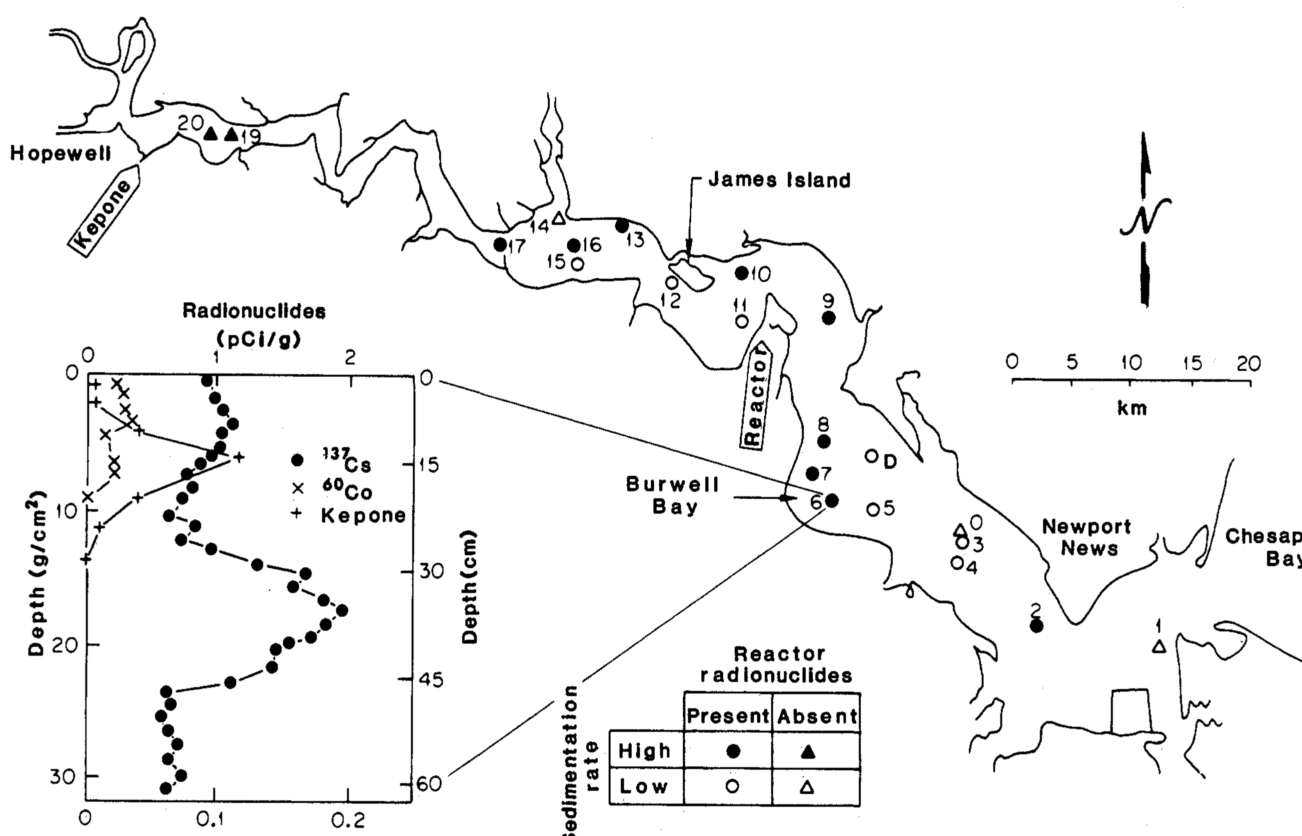

Fig. 1. Locations of sampling sites in the James River estuary. Station symbols indicate the rates of sedimentation and the presence or absence of reactor radionuclides. Sedimentation rates greater than 1 cm/year are labeled "high" and rates equal to 1 cm/year or less are labeled "low." The inset shows the profile for ^{137}Cs, ^{60}Co, and Kepone at station 6. Maxima in ^{137}Cs are believed to represent a reactor release in 1975 and the maximum deposition of fallout from atmospheric testing in 1963. The Kepone maximum corresponds to the year of greatest production, 1974.

Table 2. Observed depths to buried maxima and estimated rates of sedimentation. Asterisk indicates the core plotted in the inset of Fig. 1. Two maxima were found for ^{137}Cs at stations 6 and 13.

Station number	River kilometer	Depth of maximum Kepone (cm)	Depth of maximum ^{137}Cs (cm)	Reactor nuclides	Sedimentation rate (cm/year)
1	5			−	< 1
2	14	15	10	+	5
4	21			+	< 1
3	22			+	< 1
0	22			−	< 1
5	35			+	< 1
6*	34	15	10, 40	+	3
D	35			+	< 1
7	36	45	30	+	10
8	37	30	25	+	8
9	50	40	40	+	10
10	62	50	30	+	10
11	64			+	< 1
12	72			+	< 1
13	78	5	< 5, 20	+	2
14	82			−	< 1
15	82	3	5	+	1
16	82	20	10	+	15
17	88	30	57	+	15
19	116	> 57		−	> 19
20	119	> 56		−	> 19

clides at depths below 10 cm with several cores containing substantial concentrations of both contaminants in the deepest segment analyzed, nominally 60 cm. The highest Kepone concentrations were in the deepest segments of the two cores taken farthest upstream. The segment from 56 to 58 cm at station 19 contained 0.44 mg/kg, and the segment from 55 to 57 cm at station 20 contained 0.74 mg/kg. In the estuary proper, the highest concentration of Kepone (0.18 mg/kg) was in the segment from 46 to 48 cm at station 7. The presence of these relatively recent contaminants at such depths reflects rapid sediment accumulation at the core sites. Reactor-produced ^{134}Cs and ^{60}Co were detected only in cores taken from the middle estuary, at sites both upstream and downstream from the reactor. Depositional and nondepositional sites occur over the entire range of our sampling; no particular reach was purely depositional (Fig. 1). Because patterns of deposition and erosion in the lower James River are complex (*5*), the few cores we examined do not allow estimation of average accumulation for the entire system.

Maxima in radionuclide or Kepone concentrations at depth in the sediment indicate a deposition history, provided that biological or physical mixing has not destroyed the historical record. One core in particular, from station 6 in Burwell Bay, contained a complete 20-year-depositional record. The ^{137}Cs concentrations, plotted as a function of the total accumulated sediment (in grams per square centimeter) (inset in Fig. 1), include two subsurface maxima, corresponding to the reactor release in 1975 and the greatest fallout deposition in 1963. Reactor radionuclides ^{134}Cs and ^{60}Co are associated with the 1975 peak but not with the deeper one. The highest concentration of Kepone (0.12 mg/kg) occurs just below the 1975 ^{137}Cs peak and is associated with the 1974 Kepone production maximum.

We have estimated sediment accumulation rates based on the depths of burial of maxima (Table 2). The apparent sedimentation rates range from less than 1 cm/year to over 19 cm/year. High and low sedimentation rates are found throughout the estuary. In zones where sediments are accumulating most rapidly, mixing by organisms is expected to be too slow to destroy the historical records. Olsen (*6*) noted that for sediment accumulation rates exceeding 5 cm/year, mixing rates have little effect on the profiles observed even with mixing coefficients as high as 10 cm^2/year.

Sites where the maxima are found for both Kepone and reactor radionuclides are located throughout the estuary (from 2 to 82 km above the mouth). The depth of the Kepone maximum is consistently greater than the depth of the 1975 reactor radionuclide maximum, an indication that the resolution time is less than the difference in respective input peaks, approximately 1 year. Moreover, there is no systematic change in the relative positions of the maxima with location. We conclude that transport of particle-bound contaminants along the estuary is more rapid than can be detected with 1-year resolution. The sediment transport processes that produced the present distribution are not expected to carry highly contaminated sediment from the source area into the lower estuary without substantial dilution.

Because the highest concentrations of Kepone were found at sites with the highest rates of sediment accumulation and because Kepone at such sites is below the sediment surface, we conclude that rapid burial has occurred. The radionuclide profiles confirm rapid Kepone burial and indicate that postdepositional movement is negligible. Barring disturbance by hurricanes or dredges, the average surface sediment concentration of Kepone must decline rapidly after termination of input. Mixing with the overlying sediment during erosion or dredging would, however, give rise to Kepone concentrations lower than the present maxima. Since Kepone contamination levels in organisms are the combined result of uptake factors such as exposure to sources of contamination and loss factors such as excretion and population turnover, rapid burial of the most highly contaminated sediment is a favorable event.

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