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European Cretaceous Flints on the Coast of North America

Abstract. *Flint pebbles and nodules from the Upper Cretaceous chalks of Europe occur offshore and at many seaports along the Atlantic coast of North America, where they were brought as ship's ballast. Isolated pieces imported from Europe as gunflints also are present.*

During various geologic investigations of the coastal regions of eastern North America, we independently have encountered flint pebbles and nodules identified as derived from European outcrops of Upper Cretaceous chalks. Some of the specimens were originally believed to have been shaped by early man. Although experts later indicated that probably none of the specimens are artifacts, the circumstances leading to the presence of the pebbles and nodules may be of sufficient interest to warrant this recording; we describe them according to locality from northeast to southwest.

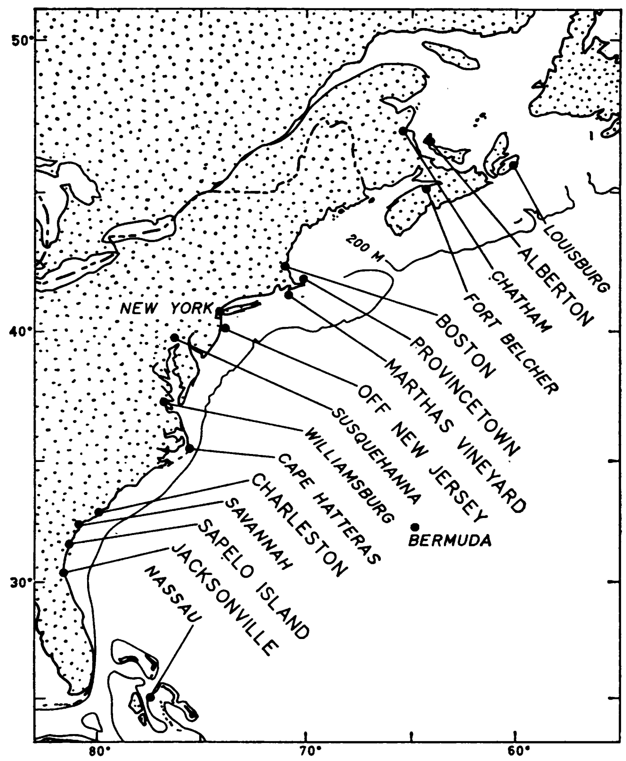
In 1965 Loring and Nota found many flint nodules on the intertidal part of a beach at Prince Edward Island—to the east of Cascumpeque Point, about 3 km south of Alberton (Fig. 1). About 100 kg of nodules 2 to 8 cm in diameter were noted among the local beach materials, which consist of fine to medium sand plus subangular pebbles of the local Triassic red sandstone. Flint is foreign to the region, and these nodules (Fig. 2A) are lithologically similar to many thousands of Upper Cretaceous ones that we had seen along the shores of England and France: gray to dark brown in color; nodule coated with a smooth opaque white crust; brittle; light-brown inclusions; clean conchoidal fractures, with light-brown patina. Thin sections made from two of the nodules showed many small Foraminifera replaced with chalcedony, and abundant sponge spicules replaced with quartz. Identification (*1*) indicated that the planktonic Foraminifera, including *Heterohelix* sp., are Late Cretaceous in age. The following information (*2*) suggests that the nodules may have been left by Jacques Cartier who left Saint-Malo, France, with two ships each of 60-ton burden. Entering the Gulf of St. Lawrence, he discovered Prince Edward Island on 30 June 1534 and explored the northern and northeastern shores. He had difficulty in getting ashore in the Alberton area: "We could find no harbour for the shore is low and skirted with sandbanks where the water is shallow. . . . We went ashore in longboats at a river [Canoe River]" (*3*). The name Canoe River was given by Cartier to what is now Cascumpeque Bay. Because of the shoals he may well have unloaded some of the ballast from Saint-Malo to enable his ships to enter over the sand banks. When this procedure failed, he "lowered sails and lay to," and went ashore in longboats.

At Chatham, New Brunswick (about 25 km above the mouth of the Miramichi River), ships formerly arrived from Europe in ballast. As usual in those days, much of the ballast was dumped in the river, but some of it washed ashore where two men (*4*) independently have found flint nodules. Some of the ballast was used for construction of the town pier that still is in use. Another man (*5*) found a large deposit of flint at Fort Belcher (Fig. 1); he said that flint ballast is present at most of the ports of Nova Scotia.

Flints from several localities in and near Boston, Massachusetts, are of the same lithology as the ones from Prince Edward Island and the English Cretaceous chalks; no similar flint outcrops in Massachusetts. In 1962 Kaye noted large quantities of flint pebbles and nodules on artificially filled land near the shore of Castle Island, South Boston. A thin section of one typical piece revealed abundant Late Cretaceous plankton forms including *Globotrucana* sp.(*1*). Among the fill was one piece (Fig. 2C) that Kaye thought might be a core from which knife blades had been struck by a Paleolithic tool maker, but later examination (*6*) failed to support this interesting belief. It was indicated (*7*) that the flinty fill had been carted to the site from army munitions ships on their return in ballast from England to the Boston Army Base during World War I. Formerly, nodules of flint also were found in the city dump area of Chelsea, just north of Boston; they had been brought by square-rigged sailing ships that berthed nearby during the 18th and 19th centuries. Nodules were collected there (*8*) for a course in flint knapping at Harvard University in 1931 and 1932. Similar flint nodules have been reported 10 km south of Boston, near the Wollaston Golf Course, where marshes adjoining the Neponset River have been filled; and 30 km to the north, at Salem, where they have been picked up (*9*) along the shore near the Beverly Bridge.

Near old wharfs on the west shore of Provincetown, Massachusetts, black flint nodules and pebbles have often been seen (*10*); some were collected about 1935 for experiments in making arrowheads and for striking fire. The flints were considered (*10*) to have come from ballast, and the belief is reasonable in view of the former importance of Provincetown as a cod-fishing center and seaport. In 1967 another flint nodule was found measuring 9 cm in diameter; it was almost black, but covered with the usual white crust that is typical of the European nodules from the Cretaceous chalks. A thin section showed it to contain much organic matter, many sponge spicules, and a few bolivinid Foraminifera—probably Upper Cretaceous (*1*).

About 1945 two huts were excavated, perhaps 150 m apart, in dunes just east of the original Provincetown harbor in Pilgrim Lake. At each site were many clay pipes and handmade nails. The pipes at one hut carried stampings that identified them as having been made between 1700 and 1720; they were stamped "RT" (for Robert Tippit), "Evans" (of Bristol, England), "Parks," or "WR."' Such pipes were introduced into England about 1688 by Dutch soldiers brought by William of Orange (William III) (*11*); two William-III pennies found in the hut confirm this date. At the other hut, where the clay pipes were unstamped but of the same type, were found at least a dozen pieces of flint exactly like the pieces from Prince Edward Island and Boston; the



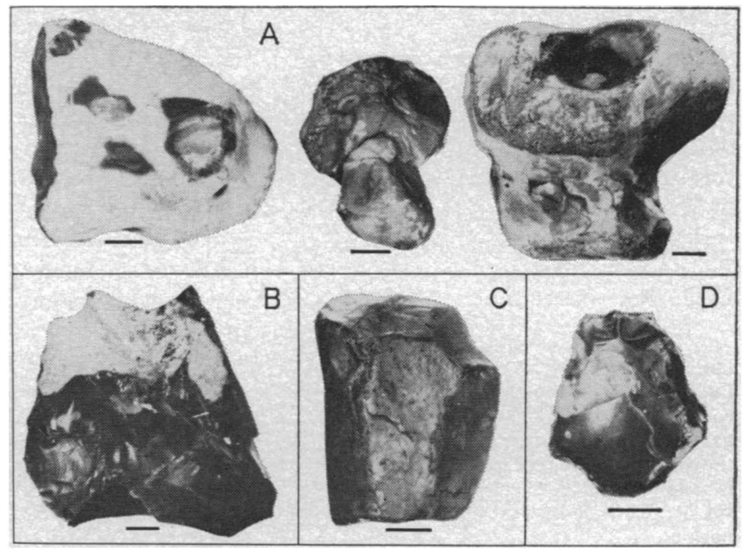


Fig. 1 (left). Localities of finds of European Cretaceous flint along the east coast of North America (large lettering), and probable sources (smaller lettering). Fig. 2 (above). Selected pieces of flint; each bar represents 1 cm. (A) Pebbles and nodules from Prince Edward Island. (B) Fragment found on the sea floor off New Jersey. (C) Prism-shaped flint from Boston. (D) Gunflint from Martha's Vineyard.

fact that some of them fit together indicates that the inhabitants of the hut had broken larger pebbles or nodules, perhaps in order to make gunflints or fire-making flints. The European origin of the flint and the proximity of the huts to the old harbor support the view that the flints came from ballast.

On the island of Martha's Vineyard in 1959 Kaye discovered a piece of European flint not associated with ballast; it was at the top of a high cliff (Gay Head) and under about 30 cm of soil; it is 3.5 cm long, with one side a smooth convex fracture (Fig. 2D), while the smaller end is notched by many small chips. Comparison with flints of flintlock firearms showed enough similarities to establish its origin as a gunflint; moreover, one side contained a highly polished spot, probably where it was held by a clamp to the hammer of the firearm.

This gunflint was determined to be of Dutch manufacture (*12*), made in the Clactonian tradition; the date of manufacture is between 1650 and 1770—probably between 1650 and 1675. Gunflints were imported from England, France, and Germany in large quantities during American colonial days and were carried throughout much of North America by trappers and Indians; they are still made for export in the town of Brannon (near Cambridge), England, the center of the gunflint industry since the 1680's (*13*). Another example is provided by an 8-kg cache of worn-out gunflints (plus other scattered flints) at Louisburg (Fig. 1), a French fortress that fell to the British in 1758; all are of French manufacture except five that are Dutch (*14*).

Early in 1967 the site of a shipwreck was found off New Jersey when the clam dredger *Trinity* of Briele, New Jersey, dredged through the "Rockpile" (40°03'N, 73°50'W; 26 m). This area is generally known to dredgers and avoided because the rocks damage the nets. George Stires, a crewman, sorted the materials that came up in the dredge, picked out an irregular flint nodule along with a mastodon tooth and other bones, and sent them to Emery. The piece of flint has the same lithology as have those from the previously described areas. A thin section revealed many traces of sponge spicules and small planktonic Foraminifera, but alteration was too great to permit generic identifications. The shape of the piece suggests a crude stone ax (Fig. 2B), but it is reported (*15*) to be definitely not an artifact. Encrusting two small spots of the nodule is a bryozoan, *Cribilina punctata* (Hassall) (*16*), whose distribution pattern includes the continental shelf off New Jersey and the depth range of the dredging. According to Stires, previous dredgings in the same area have recovered other nodular rocks and pieces of a wooden-doweled ship. Although obviously incomplete, the evidence suggests that a century or more ago a ship sank in the area, and that disintegration of her hull released ballast that included some Cretaceous flint, probably from England or France.

Susquehanna Indian graves of 1630 to 1675 (*17*) contained foreign flint considered to be from ship ballast; about eight pieces were found of which half were chips used for knives and half were unmodified beach pebbles. The last Indian on Cape Hatteras chipped tiny arrowpoints from ballast flint (*17*). Other Indians made distinctive gunflints from native flints (*13*) but never from European flints from ballast (*12*). Many Indian burials after 1640 contain pouches of 15 to 20 gunflints of English manufacture, and some burials after 1675 have ones of French manufacture. Evidently, European flint, from either ship's ballast or firearms, was widely distributed, even beyond the Mississippi River, by Indians and colonists.

Even in the earliest North American settlements the problem of waste disposal, in regard to dumping of ballast, required legal control. At Williamsburg, Virginia, a law was passed in 1691, and repeated in many subsequent years (*18*), providing for the appointment of a ballast agent in the colony and requiring (under penalty of a £10 fine—later £50) shipmasters to dump ballast ashore and above the high-water mark so as to not create obstacles to navigation. Similar circumstances were reported for another part of the continent by Dana (*19*), who thus described the off-loading of ballast at Ballast Point near the entrance of San Diego Bay, California:

> A regulation of the port forbids any ballast to be thrown overboard; accordingly, our long-boat was lined inside with rough boards and brought alongside the gangway, but where one tubful went into the boat twenty went overboard. . . . This is one of the petty frauds which many vessels practise in ports of inferior foreign nations. . . .

So much ballast was discharged at Charleston, South Carolina, in exchange for bulky cargoes of tobacco and cotton that the ballast was used as paving stone when cobbled streets became popular about 1800. Recent repaving has attempted to preserve the cobblestones for their uniqueness, particularly on Chalmers Street and Bay Street near the waterfront. Most European Cretaceous flint is too brittle for common use in paving, but a sample of this stone (*20*) is whiter and tougher than the usual variety; a thin section contained many sponge spicules and some Foraminifera, including heterohelicids and globotruncanids, indicative of Late Cretaceous age (*1*). A related use of ship's ballast is reported (*21*) in Savannah, Georgia, where the basements of harborside warehouses have been rejuvenated as restaurants and bars. The interior walls, still in their original state, are of ballast of many rock types, probably including European flint.

Rules similar to those of Williamsburg regarding the disposal of ballast were evidently followed at Sapelo Island, Georgia, where the presence is reported (*22*) of many piles of ballast stones on the marshes adjoining tidal channels. Pieces of flint, having all the characters of the English flint, are common. A thin section exhibited the usual sponge spicules and Foraminifera of Late Cretaceous age (*1*). British soldiers used English flint from ballast for making gunflints at nearby Fort Frederica, built in 1721 (*14*).

Jacksonville, Florida, resembles Charleston and Savannah in its cargoes and period of importance in transatlantic shipping; again flint is abundant, particularly in a parking lot on artificially filled ground near the Costa Bridge. A pebble (*23*) is lithologically similar to flint from previously described localities and in England; a thin section cut from the 6-cm pebble contained many sponge spicules but no identifiable Foraminifera.

About 1935 the equivalent of about a wheelbarrow load of fist-sized flint nodules was noted (*24*) on a small island near Nassau in the Bahamas. This is an area of calcareous reefs, so that the flint must have been brought by man—probably as ship's ballast.

Rock was commonly ballast for ships until about a century ago when cast iron became cheap. The small ships of ancient times usually were pulled ashore for the night, and thus the shore was a ready source of clean manageable stones for ballast. Beach materials were readily accessible for later ships also because of the small size of most of the medieval harbors that fronted the open sea. Beaches of southern England and northern France consist largely of flint pebbles, cobbles, and nodules, because these are the most resistant components of the coastal strata. The use of flint ballast in ships of western Europe probably extends at least to Viking times. Viking ships probably contributed to the large quantity of Cretaceous flint around Oslo Fjord, Norway, that has been brought in as ballast by sailing vessels; dropping of this ballast at or near the shoreline continued well into this century (*25*).

An interesting example of provenance in Scandinavia was provided by paleontological study of 120 tons of ballast and of 29 sinker pebbles (for a fishing net) found in the Swedish warship *Vasa* which sank a few minutes after casting off on her maiden voyage in 1628. Both ballast and sinkers came from the eastern shore of the Baltic Sea, opposite Stockholm where *Vasa* was built (*26*).

The region of England and France that has outcrops of Upper Cretaceous strata with flint nodules includes the European ports that handled most of the transatlantic shipping after Viking times. Accordingly, we should not be surprised to find European Cretaceous flint well represented in areas of the New World where 16th to 19th century English and French ships discharged ballast for lightening ship or in preparing to load cargo. Some sites of discharged ballast are known from the physical presence of the discarded stone; still others are to be expected in all the old seaports of the coast. Where ships of the 16th to 19th centuries sank near shore and the hulls disintegrated, some of the released ballast should have worked its way ashore with the aid of waves and currents. Flint pebbles and nodules and other diagnostic foreign rocks on the sea floor, or in the shore zone, can serve as tracers for location of sites of ancient shipwrecks, as well as being interesting examples of long-distance transportation of rock.

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Fossil Alpha-Recoil Analysis of Certain Variant Radioactive Halos

Abstract. *The distribution of alpha-radioactivity in the vicinity of uranium and of certain variant radioactive halos in biotite was investigated by the fossil alpha-recoil method. Within the limits of the method I could not confirm a previously proposed hydrothermal mechanism for the origin of certain variant halo types due to polonium isotopes.*

Microscopic examination of thin sections ($\approx 20\ \mu$) of certain minerals sometimes reveals a distinctive pattern of colored concentric rings surrounding a minute central inclusion about 0.5 to 1 μ in radius. Although these structures had long been observed by mineralogists, their origin was a mystery until almost simultaneously Joly (*1*) and Mugge (*2*) correctly attributed the phenomenon to the presence of radioactivity in the central inclusion. While in some instances the inclusions have been identified as zircon (*1*, *3*), xenotime, or monazite (*4*), the halo nuclei are often too small for petrologic analysis.

In polarized light, the appearance of the varicolored ring patterns in such anisotropic minerals as biotite suggested the designation "pleochroic halos," although "radioactive halos" is clearly more appropriate. While the radioactivity in the central inclusion may consist of α-, β-, and γ-radiation, the development of a halo is basically due only to the proportionately much higher ionization effects of the α-particles. This is an extremely fortuitous situation because, since the α-particle has a rather precise range R in a mineral for a given initial energy E, one can often ascertain not only the elements responsible for a particular halo type but also the specific isotopes. If the halo nucleus contains uranium, the α-emission from the eight α-emitters in the decay chain produces a region of radiation damage surrounding the inclusion. In certain biotites this region becomes faintly visible when about 10^8 atoms of ^{238}U have decayed; with increased α-emission a series of colored, spherically concentric shells eventually appears, corresponding to the ranges of the respective α-emitters of the ^{238}U decay chain. The three-dimensional nature of the halo becomes strikingly apparent when a sample of biotite is prepared for microscopy. The leaves of a book of mica are easily cleaved with transparent cellophane tape, and each successive layer of mica reveals a ring pattern of increasing size until the diametral section is obtained. Years ago there was great interest in the ring structure of uranium and thorium halos in investigation of the invariance of the radioactive transformation rate over geological time (*5*). It is in this connection that radioactive halos have again drawn interest (*6*).

Naturally ring sizes are always measured from diametral sections; results are best from specimens having exceptionally small nuclei. Use of a filar micrometer shows the ring radii for the uranium and thorium halos to agree very well with the calculated α-particle ranges of ^{238}U and ^{232}Th and their respective α-emitters. Thus an experimental range:energy relation for α-particles may be determined for any mineral containing well-defined uranium or thorium halos, with small central inclusions.

Certain types of halos (I call them variant halos) exist that cannot be identified with the ring structure of either the uranium or thorium halos. What is the nature of the α-emitters responsible for these variant halos? Several types of variant halos were discovered but were not claimed to be evidence of new α-emitters because radioactive-decay schemes of uranium and thorium were still being refined. Nevertheless Joly (*7*) reported three variant halo types: one he attributed to "emanation" (^{222}Rn), a dwarf having a very small radius; another was simply designated the X-halo. Others (*8–10*) have reported unusual halo sizes, and I have found halos having anomalous ring structure (*11*, *12*). For greater clarification of the variant halos, I classify as class I those rather easily identifiable with known α-emitters; as class II, those (such as Joly's X-halo) whose ring structure has not been correlated with known α-emitters. For example, Henderson reported four variant halo types: A, B, C, and D. Types A, B, and C were correctly attributed to the polonium isotopes ^{210}Po, ^{214}Po, and ^{218}Po, respectively; thus they are of class I. But I have been unable to confirm Henderson's association of the D-halo with ^{226}Ra (*13*). I confine this report to investigation of class-I halos —in particular to analysis of Henderson's proposed origin of the polonium halos.

The polonium isotopes have relatively short half-lives; any mechanism proposed for their origin must be consistent with this fact. The ^{218}Po halo (Fig. 1, left), so-called because ^{218}Po is the initiating isotope, exhibits three rings arising from successive α-decay of ^{218}Po (E_1, 6.0 Mev; r_1, 23 μ), ^{214}Po (E_2, 7.68 Mev; r_2, 34 μ), and ^{210}Po (E_3, 5.3 Mev; r_3, 19 μ). E_i and r_i denote, respectively, the α-particle kinetic energy and the corresponding average halo-ring radius. By analogy the ^{214}Po and ^{210}Po halos (Fig. 1, right) are, respectively, dual and single ring patterns. I have observed the polonium halos in many Precambrian biotites, and the halos in Fig. 1 were found in biotites from the Baltic (Norway) and Canadian shields, respectively. Since these polonium isotopes are daughter products of ^{238}U, it was initially conceived (*10*) that they were preferentially fixed out of uranium-bearing solutions at localized deposition centers along small conduits or veins within the host mineral (mica, for example).

While coloration surrounding minute veins in the mica is an indication of the flow of radioactive solutions (very weak solutions may show no staining whatsoever), it does not follow that halos that formed around small nuclei in the conduits were necessarily derived from radioactivity in solution. For example, polonium, uranium, and thorium halos also form around very small inclusions, with no visible conduit or crack in the mica connecting the halo nuclei, and it is certainly not clear that these halos are of hydrothermal origin.

An attempt to determine whether the halo nuclei were capable of acting as selective fixation sites for certain radionuclides, by electron-microprobe analysis of the halo inclusions, failed because of the small size involved. However, refinement of techniques may lead