

Shrapnel in Omaha Beach Sand

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doi: 10.2110/sedred.2011.3.4

Unlike what happens to other great battles, the passing of the years and the retelling of the story have softened the horror of Omaha Beach on D-Day. This fluke of history is doubly ironic since no other decisive battle has ever been so thoroughly reported in the official record.

— S. L.A. Marshall, 1960

The sand at Omaha Beach is golden in color, firm and fine, perfect for sunbathing and picnicking and digging, but in extent the beach is constricted. It is slightly crescent-shaped, about ten kilometers long overall. At low tide, there is a stretch of firm sand of three hundred to four hundred meters in distance. At high tide, the distance from the waterline to the one-to three-meter bank of shingle (small round stones) is a few meters.

— Stephen E. Ambrose, 1998, p. 117

INTRODUCTION

Soon after dawn on 6 June 1944—a day later than originally planned because of a fierce storm on the 5th—more than 160,000 Allied troops began the assault on Normandy, northwest France (Figure 1). It became a turning point of World War II, an invasion long planned and known as OVERLORD. More than 5,000 ships and 13,000 airplanes, the largest invasion armada in history, supported the soldiers on the ground. The fighting was furious, quickly escalating into the horror that became bloody Omaha Beach.

Omaha Beach was the code name for one of five coastal sectors in the Allied landings. From east to west, it faces the English Channel, and is about 5 mi long (8 km). Of the five D-day landing sites Omaha Beach was the largest. Bound at each end by rocky cliffs, it is a gently sloping tidal area, on average about 300 yards (273 m) between low and high-water marks (Figure 2).

German forces under the overall command of Field Marshall Erwin Rommel (1891-1944) occupied strategic points along the coast, entrenched in high ground commanding the beach. Rommel himself was in Germany, believing that the bad weather “would not permit an Allied invasion before his return” to the front (D’Este, 1983, p. 111). Arching bluffs as high as 200 ft (60 m) above Omaha Beach offered tactical defensive positions. No parts of the beach had been left uncovered of men and their weapons. Resistance was centered at the entrance to ravines, running from the shore to the plateau behind it. Opposing the landing was the German 352nd Infantry Division,

commanded by General Dietrich Kraiss, (1889-1944). Partly made up of troops from the Russian front, it was a first class fighting force that had been moved into the area in May, about 7,800 strong. Rommel’s battle plan was to stop the invasion at the water line, which he and Kraiss believed was possible. Quickly, however, one-fifth of the 352nd troops were gone.

THE BATTLE

Capturing Omaha Beach was the objective of U. S. Army forces commanded by Lieutenant General Omar Nelson Bradley (1893-1981). They numbered 34,250. The U. S. Navy provided sea transport, assisted by elements of the British Royal Navy. Strategically, the landings were necessary to join with American forces to the west at Utah Beach and with British forces at Gold Beach to the east (D’Este, 1983; Ambrose, 1997).

Very little went as originally planned for the Allies. Clouds obscured the beach. Most of the landing craft missed their target; many of them never reached the beach at all. Defenses were unexpectedly strong. The pre-landing Naval bombardment was ineffective and likely inadequate for the battle. Only 40 minutes had been allotted for air and naval bombardment (D’Este, 1983, p. 113). Few German combatants but many cattle were killed back of the beach.

Engineers struggled to remove obstacles. The waters offshore and the beaches were heavily mined. For many hours Allied troops could not get off the beach, many drowned, and the assault nearly failed. It was the most tenuous of all Normandy landings. At one point, General Bradley considered evacuating Allied forces. Historians suggest that the U. S. 1st Infantry Division (the veteran “Big Red One”), a National Guard unit (the 29th Infantry Division), and U. S. Army Rangers suffered about 3,000 casualties (Musée Omaha 6, June 1944). Actually the number of casualties was probably greater than that. More specifically, Murray and Millett (2000, p. 422) say that on the first day “approximately 2,500 Americans died on Omaha Beach.” No one will ever know that precise number, or the number of Germans who died. Though the original plan failed, a tenuous beachhead was established.

THE BEACH

On the morning of 8 June 1988, forty-four years after the landing, we collected a sample of sand on the high-tide point from Omaha Beach near the War Memorial. It had rained during the night and was raining still. The tide was out, as it had been during the landings. Mollusk shells (pelecypods and gastropods) glistened, and water ran through rills. Long before our visit the beach had been swept clean of

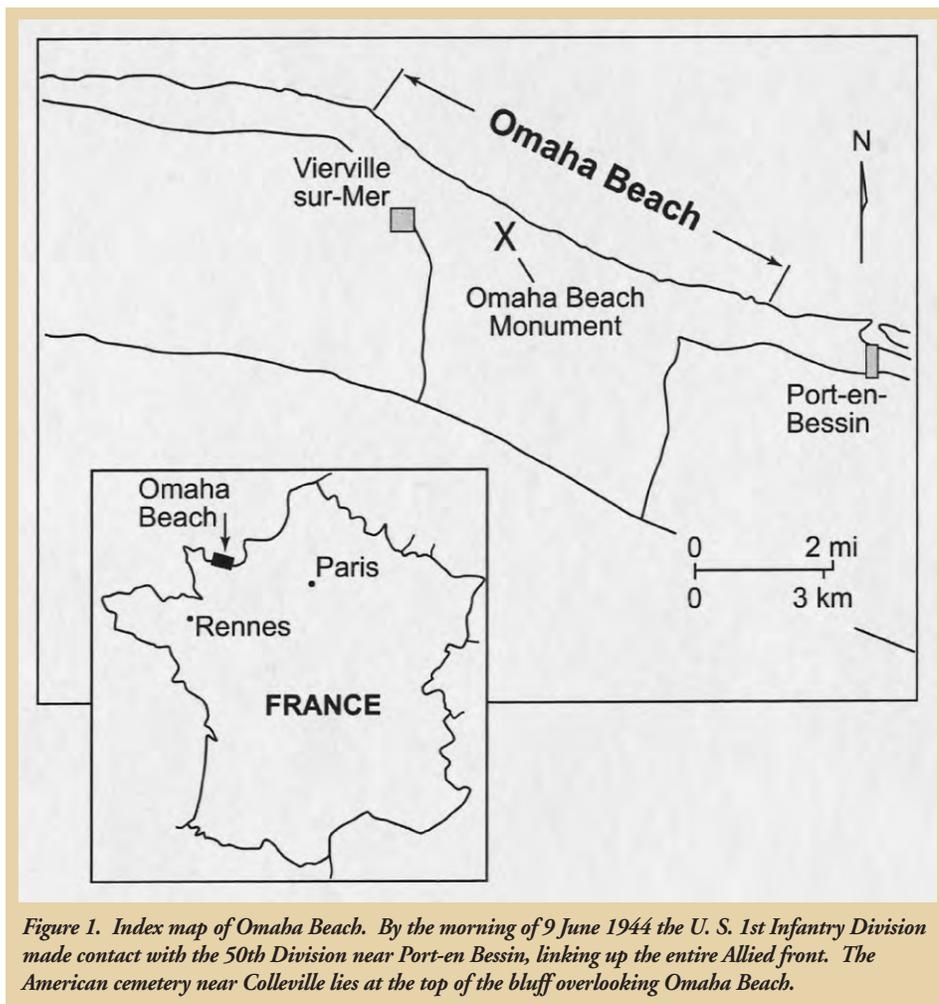


Figure 1. Index map of Omaha Beach. By the morning of 9 June 1944 the U. S. 1st Infantry Division made contact with the 50th Division near Port-en Bessin, linking up the entire Allied front. The American cemetery near Colleville lies at the top of the bluff overlooking Omaha Beach.

obvious artifacts of the war. There was little indication other than faint relics of trenches and the solitary casemates above the beach of the harrowing destruction. Collectors of sand and sandstone around the world for more than five decades, we never miss an opportunity to gather sand from shores.

THE SAND

A thin section of the sand contains a large number of angular, non-spherical, opaque grains. Like normal detrital magnetite (named for Pliny's shepherd Magnes), they were strongly magnetic. Shard-like, they were only slightly rounded. Some were well laminated. Magnetite is an isometric mineral.

These magnetite grains were also associated with small spherical beads of iron and glass. We were astonished. In a few days, we concluded that the metal and glass particles were human made—particles generated from the explosions of munitions during the Normandy landings at Omaha Beach. The initial excitement and pleasure of the discovery soon became a mixed-up one.

The sand is light-gray (10YR 7/2), well-sorted, subangular to subrounded, fine-grained (Figure 3 and cover page), and dominantly detrital quartz (78%) supplied to the coast by the Seine and several smaller rivers. Our sample also contains 9% feldspar, 4% carbonate grains (limestone clast and modern bioclasts), 4% shrapnel, 3% heavy minerals, 2% chert, other rock fragments, and beads of metal and glass. Because of the potential plasing of shrapnel and heavy minerals by waves and currents on the day we

collected our sample, we do not know how representative it is of the beach sand as a whole.

THE SHRAPNEL

Shrapnel grains range from very fine to coarse sand size (0.06 to 1.0 mm, Figure 5). Shrapnel displays a remarkable variety of shapes and degrees of roundness. Nearly all grains retain their original non-spherical shapes, but all grains, even the most shard-like, have undergone some degree of rounding of sharp edges (Figures 5 and 6). Typical of sand-grain populations, the coarsest grains generally have undergone more rounding than finer grains. Although rounding of edges is strong on some of the coarser grains, none have been abraded sufficiently to become spherical. The majority of grains have a laminate structure visible at magnifications > 200 times.

Shrapnel grains have a dull metallic luster where red and orange rust survives on parts of grains protected from abrasion. At magnifications greater than 200 times, grains display various degrees of roughness, although laminated grains display smooth surfaces up to magnifications of 500 times. Roughness is imparted by microporous surfaces produced during iron production and post-explosion corrosion products. Corrosion products, as best that we could identify them, are a mixture of hematite (Figure 7), other iron oxides and hydrates (probably goethite), unidentified mineral grains, bacteria (Figure 8), and an irresolvable mat that is likely a biofilm produced by iron-oxidizing microbes. Corrosion products coat almost all surfaces, even those not covered by rust. The corrosion layers commonly exceed 5 μm in thickness.



Figure 2. Omaha Beach (Dog Green sector) in 2001 looking south. Photo courtesy of Chris Bell.

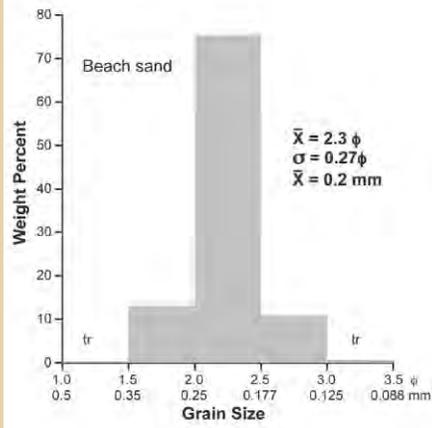


Figure 3. Histogram of sieve analysis of Omaha Beach sand.

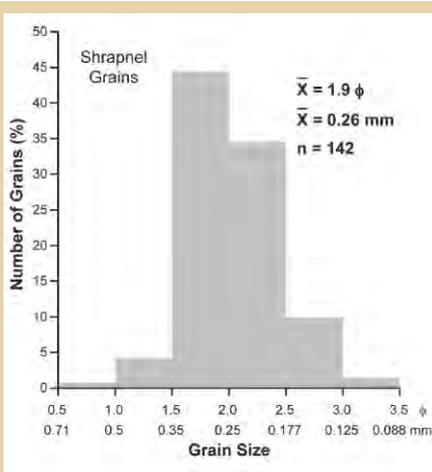


Figure 4. Histogram of shrapnel grain sizes.

The only primary crystallization texture of metal that we found is a dendritic crystal morphology (Figure 9), the most common solidification texture found in metals, according to Professor Eric Taleff of the University of Texas at Austin. The three-dimensional geometry of dendrites depends upon composition of the metal and of the cooling rate (Vander Voort, 2000).

IRON BEADS

In addition to the shrapnel, we also recovered thirteen intact spherical iron beads and five broken ones (Figures 11 to 12). They range in size from 0.1 to 0.3 mm in diameter. Most of them display a shiny luster on their outer surfaces and are nearly free of corrosion products. Two beads exhibited a matte surface. Magnifications greater than 400 times indicates that the beads are composed of intergrown iron crystals with various textures (i.e., tapered crystals, subequant polygonal

crystals, or chains of microbeads), all of which are variants of the dendritic texture.

GLASS BEADS

The twelve glass beads that we recovered are remarkably uniform in size, between 0.5 to 0.6 mm in diameter (Figures 13 and 14). Nearly all are spherical, but one glass bead is slightly oblate, another has a blister-like appendage. The surfaces of beads are mostly smooth with topographic imperfections <0.3 μm except for scattered divots and rare scratches and conchoidal spall pits (Figure 13). Divots have formed where angular, rather than conchoidal pieces, were chipped out of a bead. The beads are composed of clear glass, but they have various degrees of cloudiness, depending on the abundance of bubble inclusions (Figure 14).

The glass is not a pure silica glass. Energy dispersive spectrometer data show the presence of small amounts of calcium, sodium, and magnesium, in addition to silicon and oxygen.

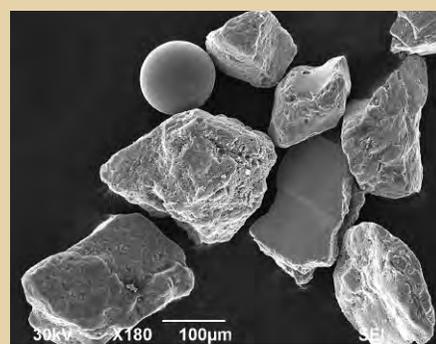


Figure 5. Scanning electron image of shrapnel grains and an iron bead. Several grains show laminated structure.

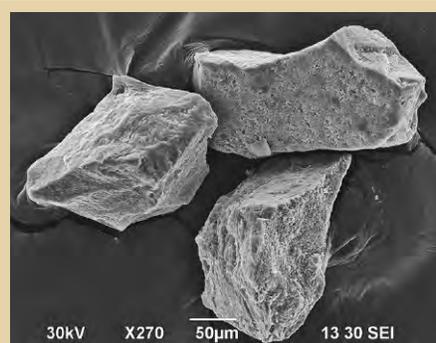


Figure 6. Abrasion has slightly blunted edges of shrapnel grains. Note the rough, corroded surfaces.

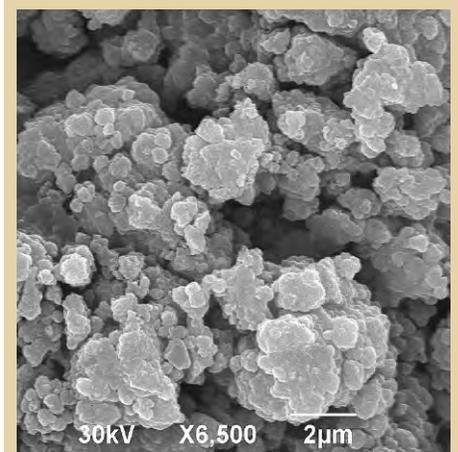


Figure 7. SEM image of poorly crystallized hematite on a rough corrosion surface.

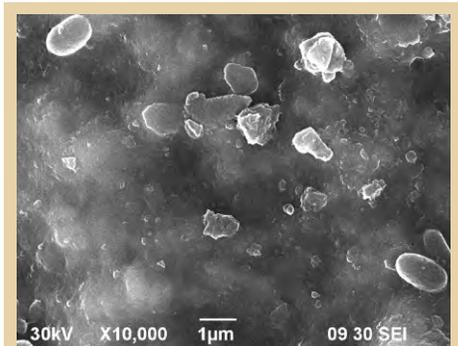


Figure 8. SEM image of bacteria on a biofilm.

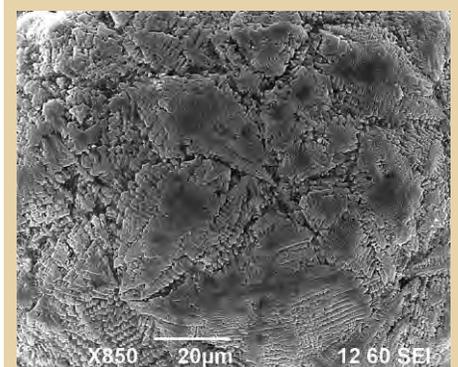


Figure 9. Complex dendritic structure of iron crystals in a shrapnel grain.

HOW THE GRAINS EVOLVED

In the years since the man-made particles formed and have been part of the beach and near-beach environments, the shrapnel grains have undergone blunting of edges that has slightly improved their roundness. There has been, however, little increase in sphericity as a measure of shape. Such a result is not surprising, given the hardness of shrapnel (Mohs hardness of iron = 5.5; steel = 6.5), and the experimental work of Kuenen (1960,

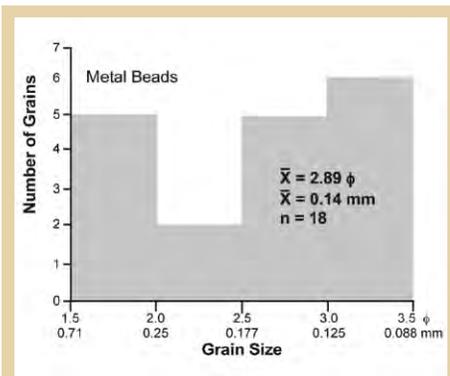


Figure 10. Histogram of iron bead sizes.



Figure 11. Dendritic structure of a broken iron bead.

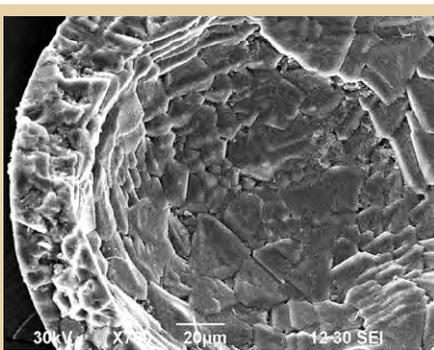


Figure 12. Polygonal structure of a broken iron bead.

1964), who long ago found that prolonged abrasion of sand-size quartz ($H=6$) by beach swash does not significantly round or modify the shape of grains (Cordua, 1998).

Importantly, the disparity in degree of rounding of grains of the same size shows that, although originating on the same day and barring no major differences in hardness, the grains have not all had the same abrasion history. Some grains spent variable amounts of time in residence on the storm beach, the

coastal berm, or an inner-shelf setting, and they have not undergone continuous abrasion on the beach.

The ubiquitous corrosion of shrapnel grains is the result of their deposition in seawater, a fluid that is optimally suited to corrode ferrous metals because of the availability of oxygen, salts, and microbes. Grain impacts during swash action kept red/orange rust from forming except on protected parts of grains. Nevertheless, at least a thin film of oxidized iron, and generally a layer of corrosion products $5\ \mu\text{m}$ thick or greater, coats shrapnel and iron beads.

Munitions explosions were hot enough to melt iron and heat quartz, generating the glass beads. Although the melting point of pure iron is 1538°C (2800°F) (Lide, 2003), iron and carbon form a eutectic system that permits melting of the mixture below 1200°C (2192°F). Cast iron, for example, melts at $\approx 1260^\circ\text{C}$ (2300°F). Michael Martinez, supervising forensic scientist and a specialist for the Bexas County, Texas, generously gave us some insight into likely explosion temperatures and iron bead structures. Martinez noted also that bomb explosions commonly produce hollow metal beads, which are also produced by phreatomagmatic eruptions, according to Morrisey et al. (2000).

Quartz melts at 1710°C ($\sim 3110^\circ\text{F}$) (Hampel and Hawley, 1973), but silica in the presence of sodium and calcium, as used in the glass-making industry, can melt around $1400\text{--}1600^\circ\text{C}$ ($\sim 2550\text{--}2900^\circ\text{F}$) (De Jong, 1989). The presence of sodium and calcium in seawater and calcium in marine shells provided the metal cations that allowed quartz to react below its melting point. It is likely that the scratches on the exterior of glass beads formed seconds after the explosion that generated them while they were soft and undergoing turbulent rotation and impact with other particles. Divots and spall scars formed from impacts with other particles when the glass had solidified, although whether this occurred in the air following the explosion (most likely), or on the beach, is uncertain.

THE RECORD

The preceding paragraphs summarize our study of shrapnel and iron and glass beads found in sand on Omaha Beach. From there



Figure 13. SEM image of glass bead with divots, conchoidal spall pits, and scratches.

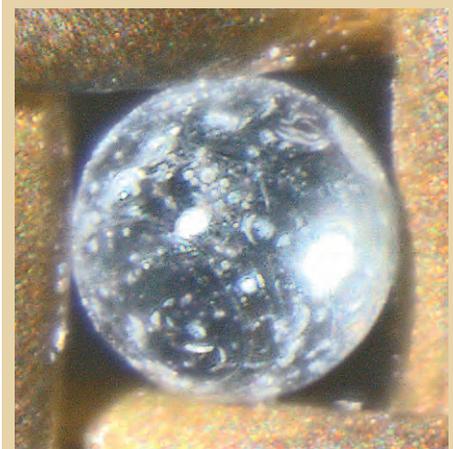


Figure 14. Glass bead caught in the opening of a 0.5 mm brass sieve. White spots are light reflections off the glass surface and off bubble inclusions in the bead.

we went to Utah Beach, a much less fiercely fought landing location. We saw no shrapnel in our only sample. We didn't go to the other landing sites.

Shrapnel survived in Omaha Beach sand for 40-plus years. Likely it is there still. How long these particles will remain is uncertain, but iron alone can probably survive beach abrasion for hundreds of thousands of years. The combination of chemical corrosion and abrasion may destroy such grains in a century or so.

Visitors to Normandy all go to see the War Memorial and so did we. Overlooking the beach, the thousands of small white crosses, democratically equal in size and in giving only bare statistics (name, rank, place of birth) evoke ghosts of those who lie there. The shrapnel in the sand at Omaha Beach, though the only remaining microscopic record of the battle, inadequately represents the extent of devastation and deaths suffered by those directly engaged in the Second World War in Europe.

ACKNOWLEDGEMENTS

We called upon and were helped by a great variety of scientists and engineers. Dr. Erik Taleff, Professor in the Department of Mechanical-Materials Engineering at the University of Texas, Austin, and his student, Alan Viosca, contributed initially to our understanding of the shrapnel. Michael Martinez, supervising forensic scientist for Bexar County, Texas, provided insight on bomb explosions and the resulting products. In an early stage of our study, Ravi Chandran, Professor in the Department of Metallurgical Engineering, University of Utah, commented on a couple SEM images of the shrapnel grains and iron beads. Christopher M. Keane and Megan Sever, Editor and Managing Editor, respectively, of the magazine *Earth*, offered suggestions and alternatives to an earlier but less scientifically complete manuscript (McBride and Picard, 2011). They gathered five photographs that were added to that piece, which was printed in *Earth*. None of them are included here. James Shea, long time editor of *The Journal of Geoscience Education*, took the time to review this article. We appreciated and used the recommendations of Xavier Janson and Wayne Wright. Bennet Picard did most of the word processing.

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Accepted August 2011

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