Torpedo-shaped Concretions and Reexamination of their Genesis

Terufumi OHNO
Department of Geology, Faculty of Science, Kyoto University, 606 Kyoto, Japan

INTRODUCTION

Torpedo-shaped concretions, first described and genetically interpreted by FIELDS (1959), are found in sandstone beds of the La Venta badlands. Their general shape is similar to that of torpedoes and they are usually arranged parallel to each other. Their peculiar shape and arrangement make them the most prominent element of the local landscape (Figure 1). In the summer of 1986, the present author had a chance to observe these torpedo-shaped concretions of the area. This paper describes the torpedo-shaped concretions and reexamines their genesis.

The author is grateful to Prof. Y. NOGAMI and Dr. T. SETOGUCHI of the Primate Research Institute, Kyoto University, who gave him the opportunity to take part in one of their South American Expeditions, and to examine the material of the present study.

GEOLOGY OF THE LA VENTA BADLANDS AND STRATIGRAPHIC DISTRIBUTION OF THE TORPEDO-SHAPED CONCRETIONS

Geology of the La Venta badlands was well studied by FIELDS (1959). The Honda Group is exposed extensively around this area, and its thickness is approximately 700 m. The group consists of gravels, sands, and clays. They are considered by him to have been deposited over a vast flood plain. It is overlain by the Mesa Conglomerate of the Pleistocene age. Fission track age of about 16 to 14.5 Ma was obtained for the upper part of this group by TAKEMURA and DANHARA (1985). FIELDS classified the group into several subunits. TAKEMURA (1983) reexamined and modified the classification. Comparison of these two classifications is given in Table 1, together with horizons where torpedo-shaped concretions occur.

Figire 1. Torpedo-shaped concretions on the weathered surface of the sandstone bed A (length of the hammer = 28 cm).

TORPEDO-SHAPED CONCRETIONS

Torpedo-shaped concretions occur mainly in sandstone beds (Table 1), which are composed of coarse to medium sand grains and contain considerable amount of granules and pebbles. These beds often show trough cross-stratifications. The torpedoes are made of the same material as the sediments around them. Examination of their thin sections reveals that the sand grains are cemented by calcite crystals, which made the concretions harder than the surrounding sediments.

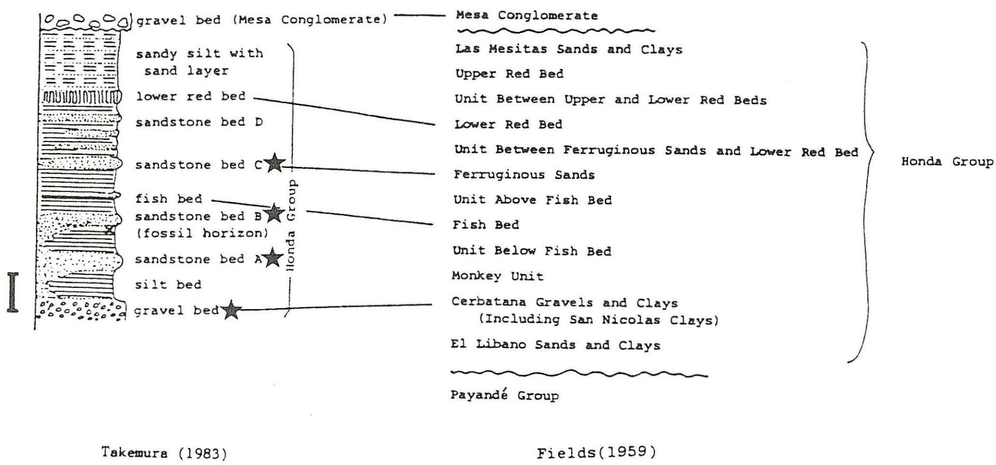


Table 1. Comparison of stratigraphy of the Miocene Honda Group in the La Venta bad lands (after TAKEMURA, 1983) with horizons where torpedo shaped concretions occur (marked with ★). Vertical bar at the left corner represents 10 m.

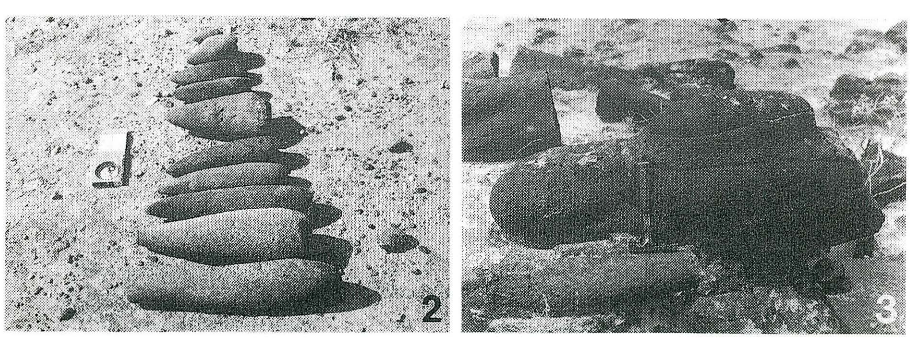


Figure 2. Variety in the shape of torpedoes (length of the compass = 17.5 cm).

Figure 3. Two storied torpedo. Note that the cross-lamination inclines to the head of the torpedo.

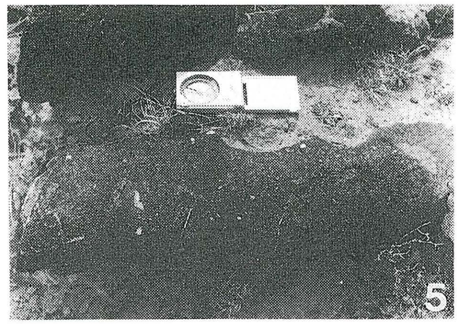


Figure 4. Torpedoes on the walls of a gorge cut into the sandstone bed B. They are arranged paralled to each other with their tails pointed to the same direction. Thus torpedotails project only from the left wall and the head only from the right wall.

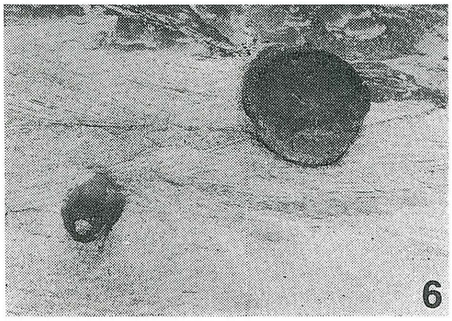
Figure 5. Torpedo cut obliquely by several parallel joints. Joint planes are cemented by calcite.

Typical torpedo-shaped concretions have hemispheric heads, cylindrical abdomens and tapered tails. Their size is variable. Smaller ones are a few cm in diameter and between 10 and 20 cm in length (Figure 2). Bigger ones have a diameter of a few decimeters and a length of a few meters. Less frequently they have a cylindrical form, with both ends in a hemispherical shape, or oval form. Torpedo-shaped concretions are often fused together horizontally. Multi-storied torpedoes are also formed through vertical fusion of torpedoes (Figure 3). Although they can be observed most easily on the horizontal weathered surface of sandstone beds, they seem to have no preferred horizon of occurrence within a single sandstone bed of a few meter thickness (Figure 4). Several of them are slightly dislocated along the joints (Figure 5). Dislocation planes are very often cemented by subsequently precipitated calcite.

RELATIONSHIP OF THE SEDIMENTARY STRUCTURES WITHIN AND OUTSIDE OF THE TORPEDO-SHAPED CONCRETIONS

Grains composing the torpedo-shaped concretions are the same as those of the sandstone surrounding them and consist mainly of sands, with a smaller amount of granules and pebbles. Frequently sedimentary structures such as laminations are visible within the torpedoes. The laminations have no preferred orientation in relation to the outer shape of the torpedoes. For example, they are inclined to both the head (Figure 3) or to the tail of the torpedoes (Figure 4). Therefore, there was no preferred water current direction during the deposition of the material forming the torpedoes. Further, there is not a single case, in which shape or orientation of laminae is controlled by the shape of the outer surface of the torpedoes; convergence of the laminae to each other towards the outer surface of the torpedo, for example, is never observed. This fact excludes the possibility of torpedo-formation through the process of filling preexisting elongated trough with sediments.

Sediments surrounding torpedoes also show sedimentary structures. For example, Figure 6 shows sand with trough cross laminations and two torpedoes within them. The slightly concave boundaries cross-lamina sets are not reflected upwards or downwards where they meet with the outer surface of the torpedoes. One of such boundaries can be traced through the inside of a torpedo. Although each of the laminae is not traceable through the inside of the torpedo, their



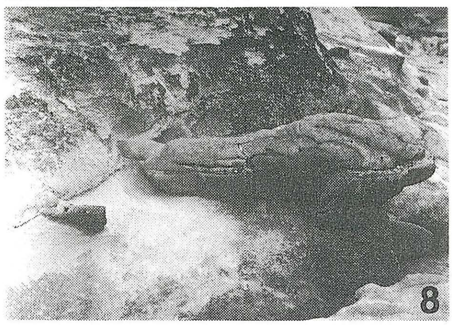
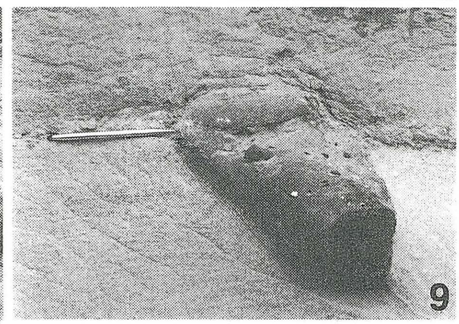



Figure 6. Torpedoes and trough cross-lamination around them (section perpendicular to the long axes of the torpedoes). Note that the torpedoes do not affect the arrangement of laminations of the sediment around them.

Figure 7. Detailed view of the smaller torpedo illustrated in Fig. 6. Note that the lower boundary of sets of trough cross-lamina continues into the inside of torpedo.

Figure 8. A pebby seam in the sandstone bed A continues into the inside of two torpedoes.

Figure 9. Detailed view of the pebbly seam running from the sandstone into the inside of the smaller torpedo in Fig. 8.

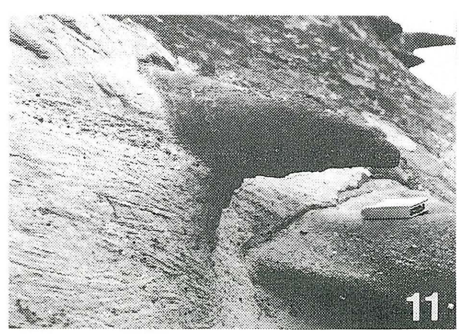



Figure 10. Torpedoes and sediments around them. Note the cross lamina inclined to the tail of the torpedo in the middle of the photograph (compare with Fig. 3).

Figure 11. Detailed view that the boundary between the pebble and granule rich part and the sandy part of the sediment continues into the inside of the torpedo.

shape in the cross section is not affected by the existence of the torpedoes and it seems quite probable that the laminations are continuous between the outside and inside of a torpedo. This observation is strengthened, when torpedoes are observed in sediments containing pebbles or granules. Figures 8 and 9 show a pebbly seam running from the surrounding sediments to the inside of the torpedoes without any break. Also the boundary between cross-lamination of granules and overlying fine sediment grains (Figures 10 and 11) runs without break into the inside of torpedoes. These facts suggest that torpedoes did not affect the sedimentary structures of sediments containing them at all.

ORIENTATION OF TORPEDOES

At each outcrop, as shown in Figures 1 and 12, torpedoes are usually arranged parallel to each other with their tails pointed in the same direction. In the studied area of about 850 m x 700 m in size in La Venta, the pointing directions of the tails of 10 torpedoes are measured at each of many outcrops of the weathered surface of sandstone beds. At each outcrop, the average pointing direction is calculated and shown in Figure 13.

The average tail pointing directions for the sandstone bed A and B are shown in the rose diagrams in Figure 14a and Figure 14b, respectively. Both of the diagrams show that the majority of the torpedo-tails are pointed to the direction between N and NWN. One average direction at one outcrop in the "gravel bed" (outcrop No. 35 in Figure 13) as well as all of the average directions obtained from five outcrops in sandstone beds in the El Dinde area, about 2 km north of the La Venta area, fall in the same interval (N to NWN). These suggest the torpedo-tails are uniformly pointed to the direction between N and NWN in a wider area around La Venta.

DISCUSSIONS

FIELDS (1959) described the torpedo-shaped concretions of the area for the first time and proposed the process of their formation. His idea is as follows. In the sandy sediments, nuclei of concretions were formed at first diagenetically. After that, there was a strong flooding which eroded the previously sedimented sandstone layer. Because the nuclei of concretions were hard enough, they resisted the eroding currents. They also provided a shelter for the not yet consolidated sediments on their downstream side. Thus after the flood there remained objects with a round top formed with a consolidated nuclei and a tail with not consolidated sandy sediments. The whole structure was burried later with sediments. The tail became hardened with time. Thus the resulting shape was a torpedo-shaped concretion.

Alternatively one can interpret the torpedoes to have been formed by the filling of pre-existing elongated troughs. Both of the interpretations require erosional surface around the torpedoes. According to FIELDS' interpretation, once there must have been an erosional surface, which bulged here and there to form surfaces of torpedoes. In case of the filling process, there must have been erosional surfaces with elongated depressions. As already described earlier in this paper, such an erosional surface is never observed around the torpedoes. Moreover, sedimentary structures inside and outside of each torpedo are continuous and not modified by the surface of the torpedoes. These facts speak against syn-sedimentary erosion-models for the torpedo-formation and indicate clearly that the torpedoes are post-depositional in origin.

An alternative mechanism is proposed here, in assuming that a ground water current is running in the direction between N and NWN through the sandstone bodies at the time of torpedo-formation. Abundant calcium carbonate of organic origin is present in the sediments of the region, which may cause high calcium carbonate content in the ground water. Around

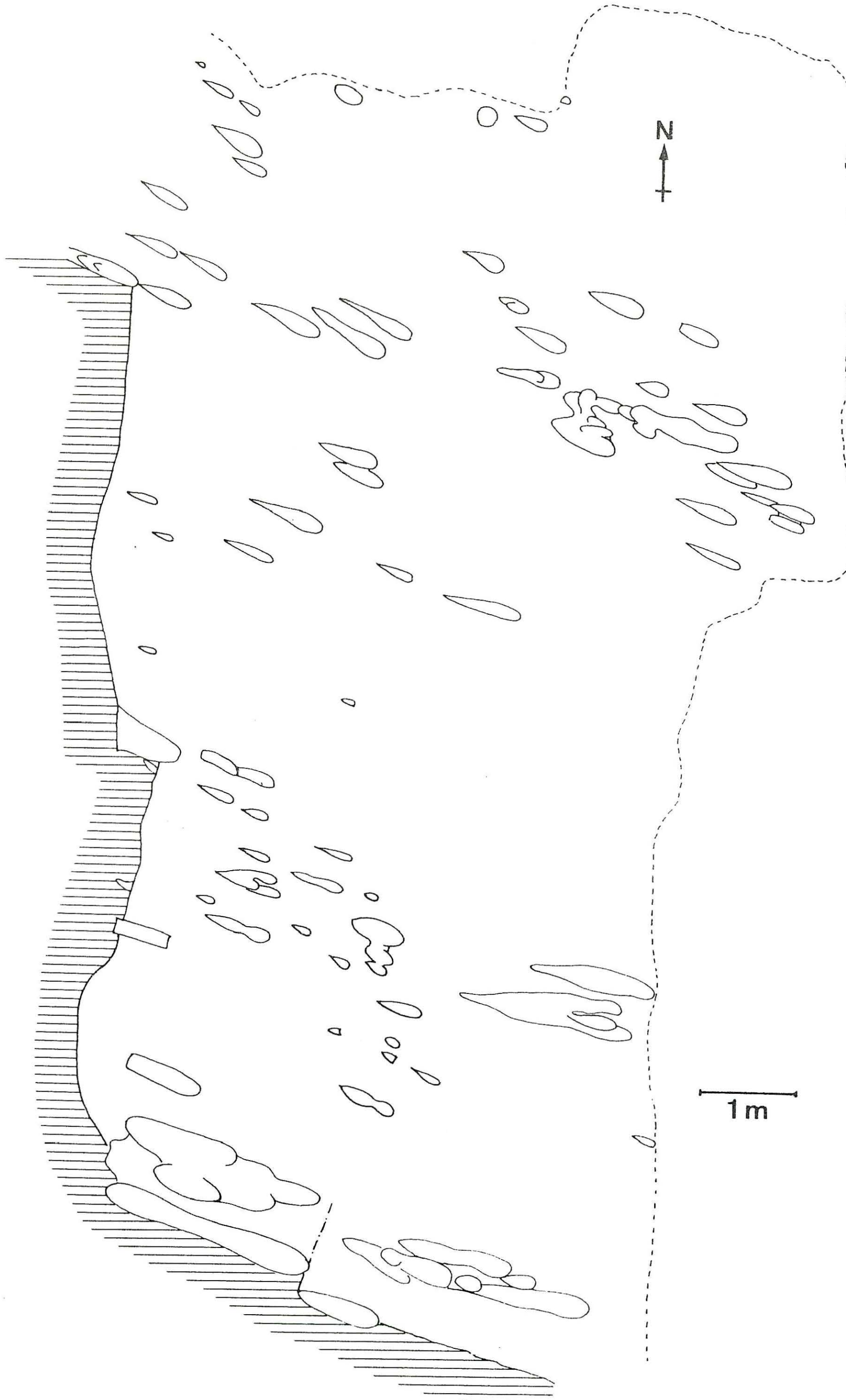


Figure 12. Sketch of a weathered surface of the bed A with torpedoes arranged parallel to each other.

Figure 13. Average pointing direction of torpedo-tails in the La Venta area.
1. dip and strike; 2. average pointing direction of 10 torpedos indicated by arrow, with outcrop number. Where torpedoes are not well exposed to show their tails and heads, only the direction of the long axes of torpedos is indicated with short bar.; 3. sandstone bed B; 4. sandstone bed A; 5. "gravel bed" of TAKEMURA; 6. mounds; 7. gorges; 8 ranch-fences.

numerous nuclei in the sandy sediments, calcium carbonate precipitates as calcite. Precipitation of calcite around the nuclei made the local calcium carbonate content lower in ground water and made the precipitation rate of calcite lower in the downstream side of the nuclei. Slow precipitation of calcite in the downstream side of the nuclei gives the tapered shape to the tail of the concretion, which is directed in the flowing direction of the ground water. Direct information is not available about the ground water current regime at that time. Yet, the tectonic setting of the region, which forms a long and narrow depression where Rio Magdalena now flows, might have restricted the general ground water current direction. The assumed general trend of the ground water current, which is in the general pointing direction of the torpedo-tails, does not deviate strongly from the general flow trend of the Rio Magdalena, and therefore, does not contradict against the above inference. Running through unconsolidated porous sandstone beds, fluctuation of the ground water current direction might have been smaller. This regionally uniform ground water current might have been responsible for the regionally parallel alignment of torpedoes with their tails pointing to the direction between N and NWN.

The exact age of the torpedo-formation is not known. Torpedoes are often cut and dislocated along the joint surface. The dislocation surface is already cemented with calcite. Thus, the formation of the torpedoes is older than the crustal movement, which formed small joint systems in the studied area.

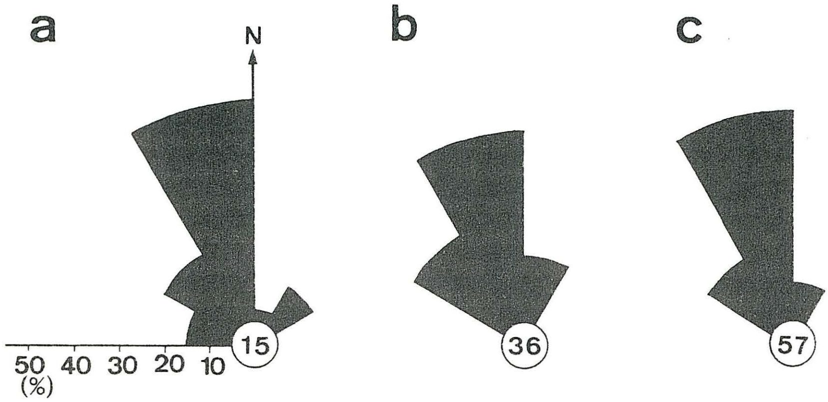


Figure 14. Rose diagrams for the average pointing direction of torpedo-tails.
a. sandstone bed A (15 outcrops); b. sandstone bed B (36 outcrops); c. all the 57 outcrops (a + b + one outcrop in gravel bed + 5 outcrops in El Dinde area).

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