14）考古金属資料の安定化処理および修復

金属器の救出

被災した文化施設からは、鉄および非鉄金属を素材とする様々な金属器が救出されました。岩手県陸前高田市立博物館からは毛抜形蕨手刀（No.3）（陸前高田市小友町岩井沢検出：陸前高田市指定文化財）（図1）をはじめとする鉄器、陸前高田市小友町常膳寺の鰐口（岩手県指定文化財）（図8）、さし鍋（陸前高田市竹駒軍見洞遺跡出土）（図9）をはじめとする銅合金資料が救出され、岩手県立博物館（以下、岩手県博）に搬送されました。

陸前高田市立博物館には小友町岩井沢出土蕨手刀の他に、２振りの蕨手刀が収蔵・展示されていて、東北地方太平洋沖地震発生時には３振りとも１階の展示室で公開されていました。巨大地震発生後、襲来した大津波によって全て流出し行方不明となりましたが、関係者の懸命な救出活動によって、2011年5月6日に３振りとも１階収蔵庫内に堆積する土砂の中から発見され（図2・3）、その後岩手県博に搬送されました（赤沼2012a、赤沼・熊谷2013）。岩手県博に搬入後ただちに、肉眼による状態観察およびX線透過写真撮影が行われました。救出した３振りの蕨手刀は今から約15年前に岩手県博で保存処理が施された資料です。その折に撮影されたX線写真と救出後に撮影された写真を比較したところ、毛抜形蕨手刀の柄の一部が欠失した点を除き、顕著な劣化の進行は認められませんでした（図4）。約15年前に実施した保存処理によって、海水損による錆化の進行が抑制されたものと思われます。

鰐口（図8）には多量の土砂が混入していたものの、被災前とほぼ変わらない状態で救出されました。一方、さし鍋（図9）は救出活動終盤、陸前高田市立博物館周辺の土砂の中からようやく、破片の状態で発見されました。

鉄資料の安定化処理および修復

処理する鉄器の外観を写真撮影しました。次にX線透過写真撮影し、資料内部の劣化状況を確認した後、表面に固着する土砂や錆を、竹串やワイヤーブラシを使って除去しました。震災前から劣化が進んでいた鉄器にはいたるところに亀裂や空隙がみられ、空隙内部にまで土砂が入り込んでいました。これらの土砂は、エアーブラシを使って可能な限り取り除きました。

錆化が進み、資料表面に黄褐色を呈する液体が吹き出ていた資料については錆層を採取し、塩素（Cl）やりん（P）といった劣化促進につながる有害元素について、EPMA分析しました。震災前に保存処理が施された蕨手刀をはじめとする鉄資料については、ドラフトチャンバー内でアセトンに浸漬し、劣化した樹脂を除去した後、精製水に浸漬し、脱塩を施しました（図5）。

脱塩はポリプロピレン製または塩ビ製コンテナで行い、脱塩液に溶出する塩化物イオン濃度が水道水以下（6ppm以下）になるまで、定期的に脱塩液を交換しながら少なくとも10日間続けました。

脱塩処理が終わった資料を超音波洗浄機で洗浄し、減

14) Stabilization and Restoration of Archaeological Metal Objects

Salvage of metal objects

Various metal items made from iron and nonferrous metals were salvaged from disaster-damaged cultural facilities. The following objects were salvaged from the RTCM and transferred to the IPMM: ironware including the *kenukigata-warabiteto* sword (No.3) (discovered in Iwaisawa, Otomo-cho, Rikuzentakata City, designated as a Rikuzentakata City cultural property) (Fig. 1) and copper alloy objects including the Buddhist ritual gong (*waniguchi*) of the Jyozenji Temple in Otomo-cho, Rikuzentakata City (designated as an Iwate Prefecture cultural property) (Fig. 8) and a pot with a spout (excavated from the Takekomagunmibora Site, Rikuzentakata City) (Fig. 9).

In addition to the *warabiteto* sword discovered in Iwaisawa, Otomo-cho, the collection of the RTCM includes two other *warabiteto* swords. All three swords had been displayed in the first floor exhibition room of the museum when the Great East Japan Earthquake occurred. The swords were washed away by the subsequent tsunami caused by the earthquake. However, due to the concentrated effort put forth during the salvage activities by the involved staff, all three swords were found on May 6, 2011 in the dirt that had collected inside the first floor repository (Figs. 2 and 3). The swords were subsequently transferred to the IPMM (Akanuma 2012a, Akanuma and Kumagai 2013). At the IPMM, the condition of the swords was visually observed, recorded and X-ray transmission imaging was performed on them immediately. Preservation treatment for the three salvaged *warabiteto* swords had also been performed at the IPMM approximately 15 years ago. When the X-ray photographs taken at that time were compared to the ones taken after the swords were salvaged, no significant deterioration was observed except for a partial loss of the handle of a *kenukigata-warabiteto* sword (Fig. 4). It is assumed that preservation treatment performed on the swords around 15 years ago had helped suppress the progression of corrosion caused by seawater damage.

Hardly any changes were observed in the condition of the salvaged *waniguchi* gong (Fig. 8) in comparison to its pre-disaster condition, except for the large amounts of dirt and sand covering it. On the other hand, the pot with a spout (Fig. 9) was found only towards the end of the salvage activities in a broken state consisting of several pieces. They were discovered in a large pile of dirt that had been removed from the interior of the RTCM which was being dried to sift out small artifacts.

Stabilization and restoration of iron objects

The external appearance of the iron objects to be treated was photographed. Then, X-ray transmission imaging was performed to assess their internal degradation. Subsequently, the dirt and sand particles affixed to the surface of the object, and the rust formed on the surface was removed using bamboo skewers and wire brushes. Cracks and voids were observed all over the archeological objects, in which degradation had already been progressing prior to the disaster. Dirt and sand had filled in those gaps. Such dirt and sand was removed to the maximum extent possible using an air brush.

As for the iron objects in which rust progression had caused a yellowish-brown liquid to spout from the surface, samples were collected from the layer of rust. Then, harmful elements which promote degradation, such as chlorine (Cl) and phosphorus (P) were analyzed by an electron probe micro-analyzer (EPMA). Iron objects such as the *warabiteto* swords which had been given preservation treatment prior to being damaged by the disaster were immersed in acetone inside a draft chamber to remove degraded resin. Then, the items were desalinated by

救出された蕨手刀
Salvaged *warabiteto* swords

修復後の蕨手刀
Post-restoration *warabiteto* swords

図1　岩手県陸前高田市立博物館から救出された蕨手刀
Fig. 1　*Warabiteto* swords salvaged from the Rikuzentakata City Museum

図2　被災した陸前高田市立博物館１階収蔵庫
Fig. 2　Disaster-damaged first floor repository of the Rikuzentakata City Museum

図3　蕨手刀の発見
Fig. 3　*Warabiteto* sword at the time of its recovery

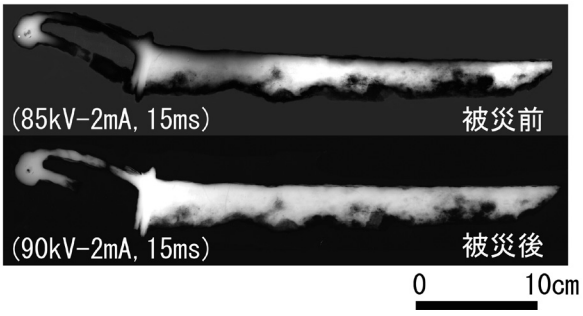

図4　被災前後に撮影されたレントゲン写真
Fig. 4　X-ray images taken before and after the disaster (Upper image: before the disaster. Lower image: after the disaster)

図5　鉄器の脱塩
Fig. 5　Desalination of ironware

図6　ハンドドリルによる錆の除去
Fig. 6　Removing rust using a hand drill

図7　エポキシパテによる欠損部の復元
Fig. 7　Restoration of defective parts using a paste epoxy

圧乾燥しました。資料表面に生成した錆をエアーブラシやハンドドリル（図6）、ワイヤーブラシを使って可能な限り取り除きました。表面をエチルアルコールで洗浄した後、30mass%のパラロイドNAD10アクリル樹脂を含むナフサ懸濁液を減圧含浸しました。樹脂含浸は2回以上繰り返しました。毛抜形蕨手刀のように大きく破損した鉄器のうち、実測図が現存する資料についてはそれを基にエポキシパテで欠失部を復元した後（図7）、岩絵の具を用いて古色仕上げしました。

銅資料の安定化処理および修復

鰐口およびさし鍋についても表面に固着する土砂を除去し、ギ酸を使って新たに発生した錆を可能な限り取り除きました。次に精製水で脱塩（図10）、エチルアルコールで脱水、ベンゾトリアゾール処理した後（図11）、鉄器同様30mass%のパラロイドNAD10アクリル樹脂を含むナフサ懸濁液を減圧含浸しました。

既述のとおり、さし鍋は大破し、著しく変形した破片の状態で救出されたため、安定化処理に移る前に微小試料片を摘出しEPMA分析しました。その結果、1mass%程度の塩素（Cl）が検出され、合わせて銅（Cu）、ヒ素（As）、錫（Sn）の合金を素材とすることがわかりました。

硬い地金で、それぞれの破片を不織布で包み整形を要する部位にアルミの板を添え、その上から少しずつ力を加え整形しました。岩手県博で保管されていた実測図を基に整形した破片をつなぎ合わせ、ほぼ被災前の状態に復元しました（図12）。

新たな発見

被災鉄器再生の過程で行われた金属考古学的調査によって、３種類の鋼が３振りの蕨手刀の製作に使用されていたことが判明しました。東北地方北部はもとより、関東および北海道でもほぼ同じ組成の鋼を素材とする鉄器が確認されています。８～９世紀に東日本において、海を渡る鉄の物質文化交流が展開されていた可能性が高いことを示唆する結果です。このように被災資料の再生は、被災した地域が歴史の上で果たした役割を再検討する重要な機会を我々に与えています。

大きく破損した資料を被災前の状態に再生できたのは、常日頃から機関連携による学術調査が行われ、重要な学術情報が複数の機関において保管されていたことに依拠します。今後もこれまでの取組を続けることによって、数多くの金属器を再生させることができると思われます。

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immersing then in purified water (Fig. 5).

The desalination was performed using containers made from polypropylene or polyvinyl chloride. The process was repeated while periodically changing the desalination liquid until the concentration of the eluted chloride ions in the liquid reached a value equal to or lower than the chloride ion concentration in tap water (6 ppm or less). Approximately 10 days were required to complete the desalination process.

The desalinated objects were washed using an ultrasonic cleaner, then were dried using low pressure. The rust collecting on the material surface was removed to the maximum extent possible using an air brush, a hand drill and/or a wire brush (Fig. 6). After cleaning the material surface with ethyl alcohol, a naphtha suspension containing 30mass% Palaroid NAD10 acrylic resin was introduced into the object by decompression method. Resin introduction was repeated two or more times. Among the considerably damaged iron objects including the *kenukigata-warabiteto* sword, those with existing surveyed drawings were treated by restoring the areas of loss based on the drawing using a paste epoxy (Fig. 7), and then giving an antique finish using natural mineral pigments.

Stabilization and restoration of copper objects

Dirt and sand fixed on the surface of the *waniguchi* gong and the pot with a spout were removed in the manner previously described, and the newly accumulated rust was removed as much as possible using formic acid. Then, the objects were desalinated using purified water (Fig. 10), dehydrated using ethyl alcohol, and treated with benzotriazole (Fig. 11). Subsequently, as with the iron objects, a naphtha suspension containing 30mass% Palaroid NAD10 acrylic resin was infused into the object by decompression method.

As described earlier, since the pot with a spout had been broken and was recovered in a state of many separate pieces, the minute pieces were extracted and analyzed by EPMA prior to performing the stabilization. As a result, approximately 1 mass% Cl was detected. The analysis also revealed that the body of the pot with a spout was made from an alloy of copper (Cu), arsenic (As) and tin (Sn).

Each piece made from this hard alloy was wrapped in a nonwoven cloth, and an aluminum sheet was placed next to the piece to be formed. Then, force was added gradually to shape the pieces into the correct form according to the surveyed drawing that had been kept at the IPMM. Shaped pieces were joined together, and then the joined areas were formed again. After completing all the treatments, the pot with a spout was restored to a state almost identical to that of its pre-disaster state (Fig. 12).

New discoveries

The archaeometallurgical analysis conducted on the disaster-damaged iron objects revealed that three types of steel were used to manufacture the three *warabiteto* swords. Ironware items made of steel with compositions almost identical to either one of these three types have been found not only in the Northern Tohoku region but also in the Kanto region and in Hokkaido.

This suggests that it is highly likely that cultural exchange of iron products had occurred in Eastern Japan in the 8th and 9th centuries. The task of stabilizing and restoring disaster-damaged objects has provided us a significant opportunity to re-evaluate the historical role the disaster-damaged regions have played in Japan's and Asia's history.

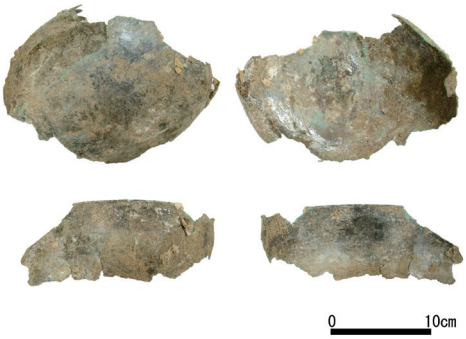
It was possible to restore heavily damaged objects back to their pre-disaster state mainly because of the scientific research that had been collaboratively conducted by relevant institutions during non-crisis times, and the fact that important scientific data had been stored at a number of institutions. It is possible to stabilize and restore many other metal cultural assets by using the methods described in this research.

Hideo Akanuma (Iwate Prefectural Museum)

救出後
Post-salvage

安定化処理後救出後
Post-stabilization treatment

図8　陸前高田市立博物館から救出された鰐口
Fig. 8　*Waniguchi* gong salvaged from Rikuzentakata City Museum



大破したさし鍋
Pieces of the shattered pot with a spout

修復されたさし鍋
Restored pot with a spout

図9　修復前後のさし鍋
Fig. 9　Stabilization and restoration of a salvaged pot with a spout

図10　さし鍋の脱塩（水浸漬）
Fig. 10　Desalinating the pot with a spout
(by soaking it in water)

図11　ベンゾトリアゾール処理
Fig. 11　Treatment using benzotriazole

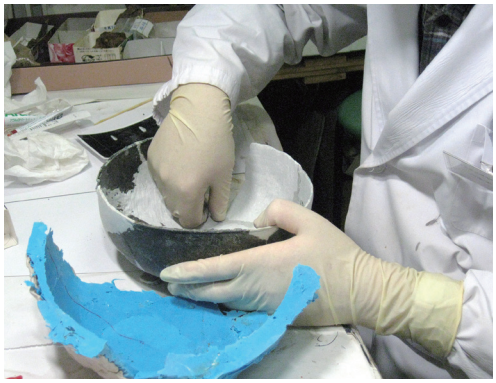


図12　破片の整形・接合
Fig. 12　Shaping and joining of the broken pieces