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New Gripping and Binding Device Greatly Improves Preparation of Natural Clasts for RFID Tracking

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New Gripping and Binding Device Greatly Improves Preparation of Natural Clasts for RFID Tracking

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Abstract: Radio frequency identification technology (RFID) has allowed for tracking of individual clasts implanted with passive integrated transponder (PIT) tags through sedimentary systems, providing recovery rates much higher than older sediment tagging methods such as painted or magnetic clasts. However, preparation of natural clasts for PIT tag implantation has been time-consuming and dangerous with rates of catastrophic failure of clasts of ~66% or more. Moreover, failure rates increase as clast size decreases. The authors present an improved methodology that provides nearly 100% success rates and allows for drilling of clasts down to 23 mm along the intermediate diameter. The gripping and binding device (GABI) prevents clasts from rotating and is effective when used in conjunction with the rhythmically applied pressure drilling technique. GABI is simple and inexpensive to build and can be used in a field setting. The improved safety and effectiveness of the method will allow for greater application of RFID tracking of natural sediment. Additionally, the ability to drill smaller clasts opens up new possibilities for research in sediment transport.

Introduction

Tracer studies have been employed for over a century to better understand rates and processes of coarse sediment transport (Foster 2000). Early methods employing painted (Leopold et al. 1966; Wilcock 1997) or magnetic (Custer et al. 1987; Gintz et al. 1996) clasts have recently been superseded by the use of radio frequency identification technology (RFID) to detect passive integrated transponder (PIT) tags implanted into clasts (e.g., Nichols 2004; Lamarre et al. 2005; Allan et al. 2006; Carré et al. 2006; Lamarre and Roy 2008; Schneider et al. 2010; Bradley and Tucker 2012; Liedermann et al. 2012; Hodge et al. 2011). RFID technology uses electromagnetic fields to transmit data wirelessly. An external antenna generates a short-range electromagnetic field that energizes PIT tags, causing them to transmit data, in this case unique identification codes, back to the antenna (e.g., Gibbons and Andrews 2004). RFID has exceptionally high recovery rates (>90%) (Bradley and Tucker 2012; Hodge et al. 2011) as compared with recovery rates of less than 40% for painted clasts (Leopold et al. 1966) and ~60% for magnetic clasts (Custer et al. 1987). Previous studies had only followed the quantity of clasts recovered. RFID is also unique because it can identify each tagged clast individually.

In the past, RFID tracking of natural sediment in streams has faced significant limitations due to the difficulty of drilling holes in natural sediment to imbed the PIT tags. Clasts very commonly failed structurally during drilling operations to insert a PIT tag or magnetic tracer (Liébault et al. 2011; Hodge et al. 2011), with failure rates of ~66% reported by Bradley and Tucker (2012). Failure occurs in both soft sedimentary rocks (Liébault et al. 2011) and crystalline rocks, which commonly fail along grain boundaries or metamorphic fabrics (Bradley and Tucker 2012). There is a risk of serious injury from flying debris due to catastrophic failure of clasts during drilling.

Failure of small clasts, in particular, limits the utility of RFID tracking of natural sediment. PIT tags suitable for sediment tracking are available down to 8 mm in length, and the technology is rapidly improving. However, the tendency for failure during drilling increases as clast size decreases, leading most researchers to focus on cobble size clasts (>64 mm in diameter). Bradley and Tucker (2012) conclude that the smallest crystalline rock clasts that could be drilled according to their protocol have a median b-axis of ~55 mm. Sedimentary clasts down to 23 mm along the b-axis were prepared for magnetic tracer insertion by Hodge et al. (2011).

Instead of tackling the problem of drilling natural sediment, an alternative is to produce artificial particles to house PIT tags. Manufactured particles of glass or tungsten coated concrete can match the density of common rocks and have been used to track bridge scour (Papanicolaou et al. 2010). Low-density plastic particles that float after being excavated from the bed have also proved useful in the study of bridge scour (Papanicolaou et al. 2010). However, the ability to track natural particles allows for more direct study of bedload transport and erosion by bedload. Existing data on the role of moderately sized sediment in eroding bedrock rivers is very limited (Springer et al. 2006), and a target for RFID tracking of natural sediment (Slaven 2013).

The objective of this study is to design an improved drilling methodology that allows for safer and easier preparation of clasts for PIT tag implantation. Drilling methodology is not welldescribed in the literature. Bradley and Tucker (2012) report that they clamped rocks to a bench and drilled with a rotary hammer drill. They also report rapid rates of drill-bit wear with each bit capable of producing an average of ~19 prepared clasts (Bradley and Tucker 2012). This method will be referred to as the vise method. The authors' goal is to improve on the vise method and develop a methodology that allows for drilling of clasts with intermediate axes less than 30 mm in length while significantly reducing the rate of catastrophic failures, thus improving safety. An ideal methodology would also be cost and time efficient so as to facilitate production of large numbers of clasts at minimal expense. Finally, portability of the drilling apparatus is desirable to allow for preparation of locally collected clasts at field sites.

Methods

A new drilling methodology was designed to minimize breakage of clasts during failure. The failure rate of clasts using this methodology was compared to the failure rate using the vise method. Two factors were identified as potentially contributing to clast failure during drilling: (1) compressive stress on the clasts due to clamping and pressure from drilling, and (2) thermal stresses due to heating of the drill bit. These factors also likely contribute to drill-bit wear. A new methodology for drilling was designed to reduce these two actors. The method presented here includes a new way of securing clasts during drilling and a technique for drill operation not explicitly described by previous researchers. To avoid stresses that can exceed the clasts' limits, the new device distributes the clamping forces with three softer faces. The combination of higher coefficient of friction between the faces and the clasts and the greater contact surface area reduces the clamping forces required to prevent rotation.

A heavy-duty hammer drill, with an 8 A motor was used in combination with carbide-tip hammer drill bits ~6.4 mm (1=4 in:) in diameter to produce holes slightly larger in width than the PIT tags (3.85 Å~ 23 mm). Two different drilling techniques were examined: (1) statically applied pressure (SAP), in which the operator attempts to maintain a constant pressure throughout drilling; and (2) rhythmically applied pressure (RAP), in which pressure of the drill toward the clast is applied and released at approximately one-second intervals. This drilling technique was used by Bradley and Tucker (2012). Three sets of conditions were compared in this study: (1) the vise method with SAP, (2) the vise method with RAP, and (3) the new methodology with RAP. For each set of conditions, 100 clasts of varying lithology with intermediate axis lengths between 30 and 225 mm were subjected to the drilling methodology. Drilling of a particular clast was deemed successful if a hole 27 Å~ 6 mm was produced and the clast remained intact and without visible cross-cutting fractures. Drilling was attempted on an additional 30 clasts with intermediate axis lengths of 20–30 mm using the new methodology with RAP to establish failure rates for small clasts in particular.

Results

GABI Device

The device designed to hold clasts during drilling is called the gripping and binding (GABI) device (Fig. 1). This device consists of a face plate of 1.9 cm thick (3=4 in:) CDX plywood attached at a 60° angle to a base plate of the same material. The base plate is clamped or screwed to a substantial work surface such as a work bench or truck tailgate. Clasts are placed into a V-shaped isolation booth, constructed of spruce/pine/fir construction studs, which can accommodate stones of varying sizes. An appropriately sized isolation blank is placed on top of the clast and clamped to the wedges; although there may be several blanks required, they can often be made from scrap material because of their small size. The clamps are tightened to hold the isolation blank in place, but are not so tight as to put excessive pressure on the clast. As drilling begins, clasts may have an initial rotation of up to 45° before they are locked into position and prevented from spinning further. The GABI device eliminates the stone's ability to rotate within the isolation booth without applying pressure to the center of the clast where the hole is being created. In the vise method, the high pressure from the compression of the workbench vise sometimes caused the rock to fail structurally and explosively. The pressures exerted on the rocks in the GABI device are much lower because of the distributed area. Additionally, the high frictional force created between the rock and the wood prevented rotation. The choice of wood as the material for the isolation booth and blanks ensures that the device will generally fail before the clast does, reducing the clast failure rate and the associated risk for the operator.

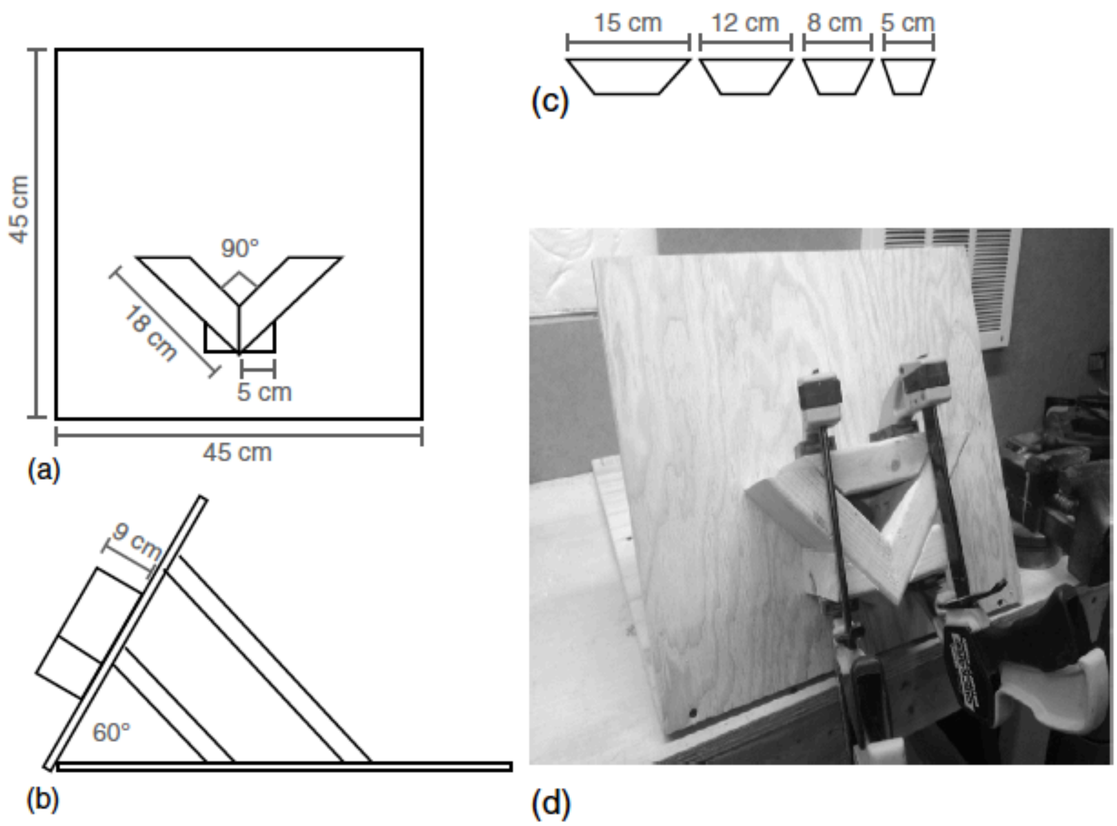

Fig. 1. (a) Front-view schematic of the GABI device: v-shaped isolation booth is fixed to a face plate and blocks are provided to clamp the isolation blanks to the booth; (b) side view of GABI: face plate is attached to a base plate at a 60° angle; (c) variously sized isolation blanks are used to complete the isolation booth for clasts of different sizes; sizes shown are examples only: the block size should be chosen to fit the particular clast being drilled; (d) isolation blanks are clamped to isolation booth; clast may rotate within isolation booth during initiation of drilling

Comparison of Methodologies

The rate and style of clast failure differed depending on the set of conditions applied. The vise method with SAP produced failures characterized by shattering that generated high-velocity projectiles. Failure rates approached 80%. The nature of failures remained unchanged when the vise method was combined with RAP. However, the failure rate decreased to 58%. Bradley and Tucker (2012) report a failure rate for the vise method with unspecified drilling technique of 66%, which is similar to the failure rate of the vise method with RAP demonstrated here.

The nature and rate of failure using the GABI with RAP was markedly different from the vise method with either SAP or RAP. Rock fragments remained in the isolation booth during all failures. The most common mechanism producing rock fragments was minor chipping of the clast near the entry hole or as the drill bit was unintentionally passed through the clast. These minor breakages did not prevent clasts from being used for RFID tracking, as the final hole was of sufficient size to hold the PIT tag. GABI with RAP had a failure rate of 0% for 100 clasts with intermediate axes greater than or equal to 30 mm in length. Failures that rendered the clasts unusable for PIT tag insertion occurred in only the smallest size category of clasts drilled: those with 23–30 mm intermediate axis lengths. These failures were characterized by a fracture crossing the clast nearly perpendicularly to the drill hole. Two failures occurred when the drill bit passed entirely through the clast. Three of the failures were in hard igneous and metamorphic rocks and one was into a soft sandstone. The ability to process small clasts using GABI with RAP was examined by attempting to drill 30 clasts with intermediate axis lengths between 23 and 30 mm. The failure rate was ~13% (4=30) for these small clasts, leading to an overall failure rate of 3%. The smallest clast successfully drilled had a b-axis length of 23 mm, which is approximately half as large as the smallest previously reported clast at 55 mm (Bradley and Tucker 2012). Drilling of clasts smaller than 30 mm along the intermediate axis was not attempted using the vise method.

In addition to greatly improving the success rate for drilling, the GABI combined with the RAP drilling method increased the lifetime of drill bits. Each drill bit produced 10–15 holes using the vise method with SAP, similar to the 19 holes per bit reported by Bradley and Tucker (2012). The combination of the GABI and the RAP drilling method produced 30–40 holes per bit.

Discussion and Conclusions

The GABI plus RAP methodology greatly improves the safety, cost, and ease of preparing natural clasts for RFID tracking. Failure rates are significantly reduced relative to previous methods, and failures are safer for the operator as debris is contained within the isolation booth. The GABI system is both inexpensive and portable, allowing for potential field preparation of clasts. Overall, these advances make tracking of natural sediment easier than it was previously and motivates examination of the advantages of tracking natural clasts as opposed to manufactured clasts. Natural clast tracking provides insight into transport processes in their natural complexity, revealing how real sediment moves, but potentially making the isolation of the impact of clast shape, size, and density more difficult than with manufactured particles made to chosen specifications. Tagged natural clasts are not visually conspicuous, which may prevent tampering in situations where there is recreational use of study sites. Tracking natural clasts is crucial when the work done by the clasts as they travel is a subject of study (Slaven 2013).

GABI also allows for the use of smaller natural particles than are commonly used for RFID tracking. The smallest clasts successfully drilled were only slightly larger than the PIT tags to be implanted in them. The use of small natural clasts for RFID tracking could potentially give insight into natural sediment transport over a wider range of sizes within a particular setting and also opens up the possibility of RFID tracking in lower-energy environments that have not previously been studied.

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