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STONE-SPLITTERS AND EXPANSIVE DEMOLITION AGENTS IN VERTEBRATE PALEONTOLOGICAL EXCAVATIONS

Mateus, O. and Araújo, R.

CICEGe, Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa, Quinta da Torre, P-2829-516 Caparica, PORTUGAL; and Museu da Lourinhã, Rua João Luis de Moura, 2530-157 Lourinhã, Portugal; omateus@fct.unl.pt and paradoxides@gmail.com

ABSTRACT

Two techniques (stone-splitters and demolition agents) are revealed to be efficient methods for breaking large stone blocks in extreme paleontological excavation. In certain conditions – where security factors, permission issues, terrain conditions, rock properties are problematic – the traditional methods for breaking large rock blocks cannot be applied (e.g. crane trucks or explosives). Using an expansive demolition agent or stone-splitters after drilling equidistant holes not only allows a cheap, quick and safe solution but also permits precise removal of up to 9 ton blocks.
Stone-splitters are a three-part tool that when inserted linearly and equidistantly along a brittle rock mass cause a precise fracture.

RESUMO [in Portuguese]

Duas técnicas (guilhos e agentes demolidores) revelaram-se eficientes para remover grandes blocos em escavações paleontológicas difíceis. Em determinadas condições – em que factores de segurança, questões burocráticas, condições de terreno e propriedades da rocha são problemáticas – os métodos tradicionais para demolir grandes massas de rocha (e.g. retro-escavadoras ou explosivos) não podem ser aplicados. Após se perfurarem buracos equidistantes, os guilhos e os agentes demolidores expansivos não só são soluções baratas, rápidas e seguras, como também permite uma remoção precisa de blocos com, pelo menos, nove toneladas. O guilho é uma ferramenta constituída por três partes que quando incrustada linearmente e em orifícios equidistantes na rocha permite uma factura precisa.

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INTRODUCTION

Some paleontological excavations require the removal of massive overburden composed of hard rock bodies. Collecting in such conditions often requires the use of explosives (that could damage the fossils) or heavy machinery. Moreover, explosives and heavy machinery (e.g. bulldozers, crane trucks) may not be a solution due to security factors, permission issues, terrain conditions, and rock properties. On the one hand, crane trucks are not always able to access the fossil sites and explosives are also avoided due to high accident risk, the need of specific training, requirement of formal permissions, and the danger of damaging the fossils. Due to several constraints, some rocks and layers have to be removed by hand, using a pneumatic or electric jackhammer, which is time-consuming, causes rapid equipment deterioration, and is physically exhausting.

This paper introduces two techniques that may be a rapid and useful alternative for breaking big rock blocks and overburden. Combining both demolition agents and stone-splitters allows removal of considerable large-dimension blocks (fig. 1) without the drawbacks of traditional methods.

Fig. 1 – Procedure to use expansive cement: A- drill the holes using a hammer drill; B- transfer the expansive demolition agent to a clean bucket; C- mix homogeneously with the same proportion of water; D- pour the expansive cement in the drill holes previously opened.

These techniques were tested in Portugal, where most of the dinosaur finds are made on the seashore cliffs in Late Jurassic terrestrial sediments, which comprise a sequence of intercalated hard sandstone and mudstone. We have successfully applied both expansive agents and stone-splitters during the paleontological excavations of 2004 and 2006 (fig. 2).

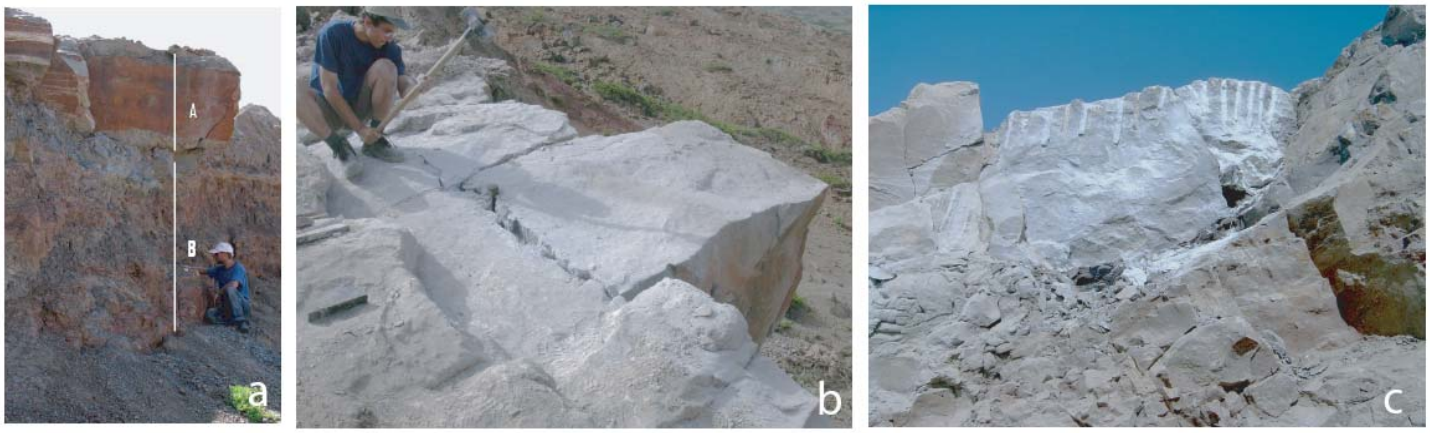

Fig. 2 – (a) Aspect of the sandstone layer A, above the bone-bearing layer B. Main block removed with combined technique stone-splitters and expansive cement, viewed from (b) top before removal, and (c) side after removal (drill holes still visible).

EXPANSIVE DEMOLITION AGENT

When mixed with water, expansive cement forms an aqueous slurry that can reach expansion stresses up to 11MPa – unit of pressure force by unit of area – forcing the rock to break (information from Crackamite®). When properly used, it can create a clear splitting line. Much information about the usage, application and composition of expansive demolition can be extracted from the patent record (see references below). Most of the patents describe expansive demolition agents made of quicklime crystals sizing 10 to 100µm (Kawano et al. 1982, Sato et al. 1987, Makino et al. 1988) reacting by hydration with water. However, this reaction can be extremely quick and release a lot of heat up to a point where the slurry reaches its ebullition point, producing gas and increasing the risk of explosion (Kawano et al. 1982, Sato et al. 1987, Makino et al. 1988). The reaction can hydrate rapidly and therefore some formulae add a fluidization agent and hydroxycarboxylic agent, in order to reduce the reaction speed. A careful reading and comprehension of the expansive agents instructions should be accomplished before any procedure. Nowadays some formulae do not present these risks (e.g. Sato et al. 1987), being constituted with calcium-alumino-ferrite, free lime and magnesia and reaction moderator components.

Procedures: A successful detachment of the block from the main rock body is a function of the following variables (fig. 3, table 1): (i) the physical position of the splitting line (i.e. how many tons of rock are going to be detached); (ii) the number of drill holes (i.e. distance between holes); (iii) depth of the drill holes (i.e. amount of cement used and the diameter of the drill); (iv) the hardness and thickness of the layer to be demolished (or in technical terms the tensile and compressive stress intrinsic to the rock); (v) the angle of the drill hole in relation to the rock body (80 to 90º); (vi) ratio between water and expansive demolition agent (normally the expansion capabilities decrease with a larger amount of water. This depends on the technical specifications of each product but, in general, 0.3 water/demolition agent); (vii) the diameter of the drill (the larger the drill, the smaller the expansion power of the demolition agent, or in other words the smaller the hole, the more expansive power potentially is available); (viii) the amount of time given for the demolition agent to react (optimum is 24h); (ix) rock and water temperature (the cooler the temperature, the smaller the expansive stress). Crackamite® and other companies provide technical graphics demonstrating the relation between these variables. As an empirical rule, around midday may be the best time of the day to use expansive demolition agents since it is expectable to be the hottest day temperature, and will coincide with the maximum expansion rate of the expansive agent.

After considering the factors explained above hammer drill. Each hole takes about thirty minutes to one hour in hard sandstone to make with a hammer drill. While drilling, pour water in the holes and switch systematically from one hole to the other. Once the mixture has the right viscosity, every drill hole can be filled almost to the top of the opening. Mix homogeneously the demolition agent and water using an appropriate mixer (although hands can also be used). Pour the slurry in the holes up to the top and wait 24 to 48h, according to the recommendations of the product. Sometimes the effect of the demolition agent might not be enough, and stone-splitters or iron bars working as levers may be need to be used to remove the block (fig. 3; table 1). During the procedure is simple. Drill the holes using a expansion, the expansive agent does not extrude through the top of the drill hole. After expansion and breaking, the expansive agent transforms into a non-cemented powdered secondary product, easy to remove and dispose of.

There are no apparent environmental problems associated with usage of expansive demolition agents. At the end of the applications a small amount of apparently innocuous powder remains. In comparison with explosives, using expansive demolition agents is environmentally friendly (in terms of vibration, residues, and sound disturbance) and fossils and surrounding formations are less likely to be damaged.

Table 1 – Type of rock *versus* distance between drill holes using different diameter drills (adapted information from CBA® EXPANSIVOS).

Type of rock	**Distance between drill holes, using drill diameter of 4cm, in cm**	**Distance between drill holes, using drill diameter of 4.5 cm, in cm**
Less hard rock (like mudstones)	45	60
Hard stone (like sandstones)	30	40
Very hard rock (fresh granite)	20	30

STONE SPLITTERS

Stone-splitters (also known as feathers and wedges) are a simple and old device used since the Roman Empire. They consist of three metal pieces: one wedge and two escorts or guides (fig. 3). The wedge is rectangular in cross-section, with a straight shaft that narrows downwards. The escorts are semicircular in cross section, with the rounded side for contact with the rock and the flat opposite face in contact with the wedge. The shaft is straight, except at the top, where it bends to the sides. Since such metal pieces are simple in their architecture they can be produced by any blacksmith, being adapted to the diameter of the drill holes. Besides being shock-resistant, the metal should be smooth in order to avoid friction with the rock and between metal pieces (fig.3).

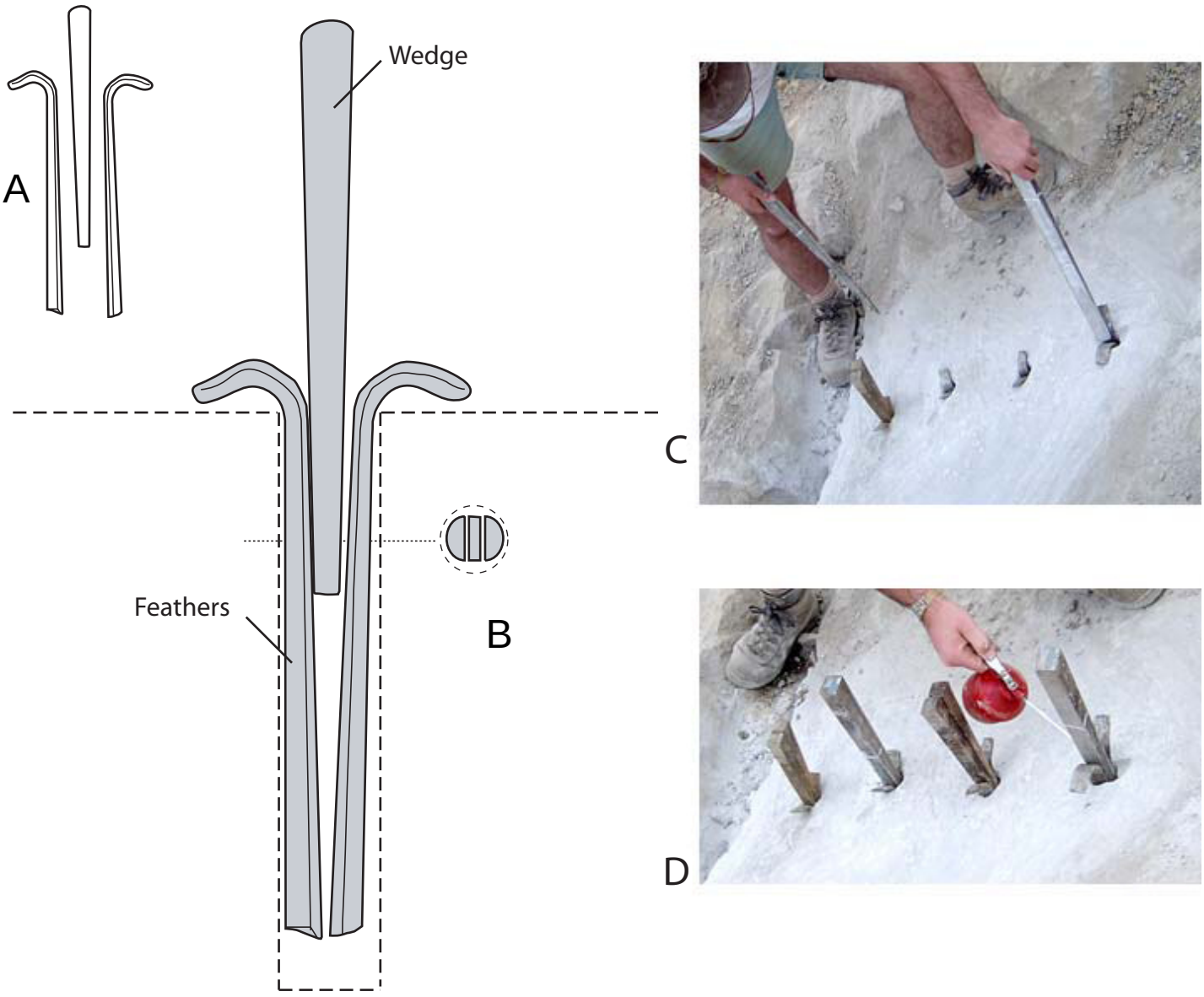

Fig. 3 – Stone-splitters: A- general aspect of the three parts of the stone-splitter; B- cross-section; C- inserting stone-splitters in the rock; C- putting oil between the wedge and the feathers facilitates the sliding.

Procedures: Existing rock cracks and weak areas are preferable when deciding the position of the splitting line. Several drill holes have to be made along the splitting line using a hammer drill, where the distance between the drills holes depends on the layer thickness and hardness of the rock. In general, drill holes may be about 20 cm apart, but harder or thicker stones require smaller distances between drill holes. The depth of the drill holes should be at least one third of the thickness of the layer of stone to be broken. Harder stone requires deeper drill holes. When drilling, some water should be poured in the hole in order to cool the drill.

The diameter of the hole should be similar to the stone-splitter diameter, and wide enough to adjust the two escorts of the stone-splitter. Harder rocks may require larger stone-splitters (up to 3 cm thick).

Once the two escorts are inserted in the hole, the thinner end of wedge is adjusted in between. Oil may be applied to facilitate the sliding of the wedge between the escorts when the wedge has already firmly penetrated in the drill hole. Oil should be used with caution in order to avoid unwanted jigs of the stone-splitters. Since each drill hole has a stone-splitter, one should hammer down the wedge, making it penetrate between the escort. A few hammer hits on each wedge should be enough, avoiding differential penetration (meaning stone-splitters penetrating more than others) along the splitting line. If everything works normally, the stone splits a few minutes to an hour later, depending on the size, thickness and

hardness of the rock. Soaking the splitting line with water helps to weaken the crack. The stones splitters can be re-used.

Cliff slopes can be unstable and potentially harmful for workers. Nevertheless, double caution when working nearby cliff slopes face when the stone splitters or expansive agents are being used since they would get even more unstable.

Final Comments

Summarizing, some advantages of these techniques are:

- The two techniques here presented are especially useful to break big blocks, and are an easy-to-use alternative to explosives and heavy machinery.
- Contrary to explosives and heavy machinery (tilt-hammer and bulldozer) these techniques do not transmit shock vibration to the fossils, thus they are suitable for paleontological excavations.
- Stone-splitters and expansive demolition agents are very easily portable devices.
- In contrast to explosives, there is no need of special authorization, for either stone-splitters or expansive demolition agents.
- Costs associated with these techniques are – relative to explosives or bulldozers – extremely low.
- Low environmental costs – contrarily to explosives, for example.

And, some disadvantages are:

- In low temperature circumstances the expansive demolition agent the expansion stresses are much lower.
- The application process of expansive demolition agents require more time than explosives.
- Stone-splitters and/or expansive agents can also be used on a small scale to make precise fractures where they are desired. In laboratory preparation where noise- and or dust-pollution can prevent hard hammering or sawing, these techniques are potentially useful.

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