Natural or artificial: Fujian rock markings

By ROBERT G. BEDNARIK

Many years ago this journal featured a major paper dedicated to 'The discrimination of rock markings' (Bednarik 1994), the purpose of which was to provide guidance in the secure differentiation between natural and anthropogenic rock surface features. It presented a nomenclature dividing all rock markings into six classes, of which five are natural features and one defines rock markings occasioned by humans. The latter were subdivided into two types: those made accidentally or incidentally, such as by vehicles, steel cables or rock drilling equipment; and those made deliberately by humans, also known as 'rock art'. This brief report is intended to be a supplement to that paper, introducing a form of newly identified natural rock marking.

Just a few hundred metres off the coast of Fujian Region in China, near Dongshan in that state's far south, lies the small and picturesque island of Dong Men Yu. It consists essentially of piles of very heavily weathered granite tors and is covered by recently introduced vegetation, dominated by Australian species. The island has been developed into a tourist destination and features walking tracks leading to various rock formations. It provides also an excellent demonstration of the kinds of weathering phenomena so well known from granite, such as tafoni (Dragovich 1969; Martini 1978; Smith 1978) and deeply developed honeycomb weathering. However, one type of geological phenomenon found in various places has not been described before. Since it can easily be misinterpreted as rock art and is very likely to occur elsewhere in the world it deserves a clear definition.

The feature being described here presents itself as

***Figure 1.** Rock markings on granite at Dong Men Yu Island near Dongshan, Fujian Region, China.*

a series of linear grooves that range from deep to shallow, that are of reasonably regular spacing and are arranged in a radial pattern. The arrangements occupy from one to three square metres each. It is their visual impact of the regularity and symmetry that invites interpretation as a humanly created, deliberate design (Fig. 1). Intention is perhaps further emphasised by the central feature, an amorphous shape of granite that seems to be of slightly different constitution. It is distinctly separated from the pronounced edge from which the radial grooves commence, and in various cases seems to have eroded completely (e.g. in the specimen of Fig. 1). It is easy to visualise this central feature as the Sun and the radial features as its rays. The example shown in Figure 1 is regarded as a very ancient Sun symbol. However, this kind of arrangement can be found in many other instances on the island and can be seen in any orientation. In some cases, the block in contact with the modified portion of the boulder features a distinct recess seemingly allowing the central feature to rest in it.

A typical aspect of the phenomenon is that the grooves are always wider and deeper where they commence from the distinctive, semicircular or arcuate edge surrounding the central feature. They may be as wide as 10–12 cm and almost as deep, but then decrease gradually in width with increasing distance from the edge. In many cases, these lines end in fine fissures, which in some cases may be up to 1.7 m long. These fissures, which are occasionally also discernible in the deeper and wider sections of the grooves, clearly indicate that the grooves were not made by human action, but that they are essentially weathering phenomena developed along weakened aspects of the rock fabric. This raises the question, what caused the radially arranged fissures and the modified contiguous zones? Similarly, what accounts for the rather amorphous, sometimes bulbous central feature that forms part of the overall phenomenon where it is not completely eroded?

It is proposed that these phenomena can be explained as the result of tribological effects (Bednarik 2019). These derive from massive impact as falling blocks collided with stationary ones in the geological past. In classical mechanics, kinetic energy (*KE*, in J) is equal to half of an object's mass (1/2 *m*) multiplied by the velocity squared:

$$KE = 0.5mv^2 \quad (1),$$

where m is mass in kg and v = velocity in m/sec. Therefore the kinetic energy of a falling block of dozens of tonnes amounts to tens of thousands of joules.

A suddenly applied impact load will result in structural responses significantly greater than for a load of the same magnitude but applied gradually. The kinetic energy of the moving block is transferred to the contact areas of the colliding objects. Each collision between granite blocks was accompanied by the release of kinetic energy. As an object falls from rest, its gravitational potential energy is converted to kinetic energy. The shock waves propagated by the impact travel through both objects affected by it, matter is compressed, pressure will be vastly increased and there will be a rise in temperature. As a result of the deformations and vibrations induced in the struck object, sound energy will also be released. However, most of the applied force is absorbed by the material struck, which behaves as if it were more brittle than it would otherwise be. The shock waves travel in circular or arcuate patterns (Fig. 2), compressing the rock until resisted by the inertia of the impacted rock mass (Gong et al. 2012). A crushed zone develops in the vicinity of the impact area, forming an arc or partial circle centred on the point of impact. The tensile tail of the propagating pressure wave then causes radial fractures to spread from the edge of the zone crushed by com-

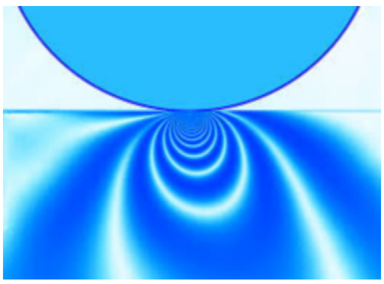

***Figure 2.** Stresses in a contact area with slight tangentiality, rendered visible by photoelasticity.*

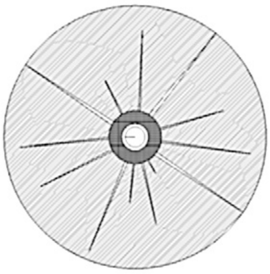

Figure 3. *Affected zones in a rock mass under the action of explosives. The dark area represents the crushed zone, and the radial tension fractures extend well beyond it (after Guerra et al. 2013).*

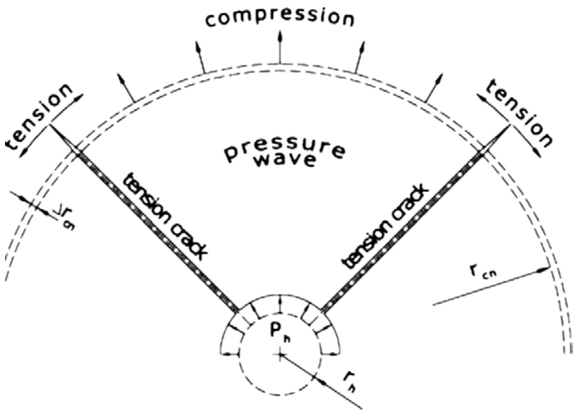

Figure 4. *Schematic depiction of radial tension fractures formation (after Torbica and Lapčević 2018).*

pressive force. These result from the expansion of matter in the deformed zone. The lengths of these fissures are determined by the respective crack velocities: the higher the crack velocity the greater the extent of the radial fracture. The size of the crushed zone and the length of the radial fractures depend on their peak pressure and frequency. The remaining kinetic energy is dissipated in tensile stress responding to the deformation of the already modified rock mass impacting on the otherwise unaltered rock. The linear fractures arise as in any rock subjected to impact (Giacomini et al. 2009), but their layout is governed by the distinctive outer boundary of the arcuate zone of deformation.

Since the mechanism of this geological process has not been described before we have in explaining it drawn on the well-understood effects of explosives on rock (McHugh 1983; Donzé et al. 1997; Esen et al. 2003; Banadaki and Mohanty 2012; Guerra et al. 2013; Torbica and Lapčević 2014, 2018). Despite the differences between surficial kinetic impact versus blasting, the underlying principles are similar. In the latter case, the effects form a circular pattern because the source of the shock is embedded within the rock (Fig. 3). The collision of blocks impacts on their surfaces; therefore the pattern represents only a partial circle (Fig. 4; cf. Fig. 1). There are, however, two hypotheses explaining the relationship between the crushed zone and the radial cracks in the effects of explosives. The dominant version perceives the radial cracks as projecting well beyond the limit of the central crushed zone. Guerra et al. (2013), in contrast, present experimental evidence showing that the location of propagating crack tips trails significantly behind the shock wave in Plexiglas cubes. However, the phenomenon presented here confirms that the stress fractures extend far beyond the zone of central deformation and we suggest that Plexiglas may not be a suitable material to replicate the process correctly.

The parts of the radial fissures that are nearest to the sharply delineated arc is also accompanied by zones of deformed rock fabric. These become narrow progressively with increasing distance from the arc until the fractures continue without weakened zones. These zones of deformation were subjected to increased rates of weathering, relative to the unaffected rock. The large zone within the distinctive arcuate depression has been weathered to an amorphous shape, while the weakened zones along the radial fissures have weathered to deep and wide, mostly V-shaped grooves (Fig. 5). All eroded surfaces, however, now present deeply weathered characteristics, suggesting that the impacts occurred in the geologically distant past.

The phenomena observed on Fujian granite are thus explained fully. They present features easily perceived as anthropogenic creations, but they are fully

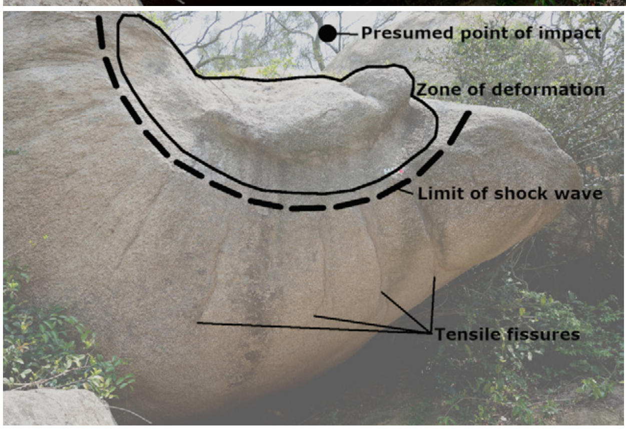

Figure 5. *A second arrangement of rock markings on Dong Men Yu Island, with an interpretation of main features.*

Figure 6. *A third specimen from the site, showing clear separation of the identified zones.*

natural phenomena and they are far too ancient to be humanly made. At the time the impacts occurred, the features would have been hardly noticeable. They only became visually as distinctive as they are today through selective weathering, which eroded the modified rock at much greater rates. Therefore, in the taxonomy of rock surface markings (Bednarik 1994), they belong to the category GP2, *naturally enhanced inherent markings* (cf. also Bednarik 2007: 18–20). It is proposed that this newly recognised phenomenon be named '*compressive-tensile rock markings*' (Fig. 6).

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