SHOCK-INDUCED SPALLATION IN TRIASSIC BUNTSANDSTEIN CONGLOMERATES (SPAIN): AN IMPACT MARKER IN THE VICINITY OF LARGE IMPACTS

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In fracture mechanics, spallation is a well-known process typically combining compressive and tensile stress. Spallation occurs when a dynamic compressive pulse impinges on a free surface, where it is reflected as a rarefaction pulse. The associated tensile stress may lead to internal spallation fractures (Fig.1 a) and to complete spalls detaching from the free surface.

Fig.1. Spallation fractures in experimentally shocked ARMCO iron (a) and in naturally impact-shocked quartzite cobbles. b, c: Internal spall fractures and a nearly detached spall in c. d, e: Spallation craters. Note the central mound in d, and the opposite craters in e.

Here, we report on the natural occurrence of spallation in Triassic Buntsandstein conglomerates induced by shock waves from nearby large impacts. The conglomerates are exposed in a large area (several 1000 km²) and surround the Azuara impact structure and especially its newly established [1, 2] Rubielos de la Cérida companion impact structure in NE Spain (Fig.2).

The conglomerates are in general composed of quartzite cobbles in a sandy matrix, and they are well known among geologists because of the distinctly pock-marked and cratered cobble surfaces. Commonly, these deformations are considered to have resulted from pressure dissolution by overburden or/and tectonic compression. Recent studies [3] show that there is no dissolution evidence and that the peculiar features and a distinct macroscopic and microscopic sub-parallel fracturing are better explained by dynamic deformation in the Azuara/Rubielos de la Cérida impact event. Among the different aspects of these deformations [3], we consider spallation a very effective and macroscopically significant process.

Fig.1 shows typical macroscopic spallation features in cobbles sampled from the Buntsandstein exposures. The samples have sets of distinctly open sub-parallel fractures with a very small spacing. There is no shearing, and the materials are not broken to pieces. An origin from quasi-static tectonic

ndeformation is hardly to understand physically. We specially point out the spall fractures (arrows) mirroring the surface of the cobble. For geometrical reasons, this is expected to occur as a result of the reflection of a dynamic pulse at the free surface. In the case of the Buntsandstein cobbles, there was not a free surface in the strict sense but a distinct contrast of shock-wave impedance between the very dense quartzite cobbles and the sandy, porous matrix. Perfect opposite spall craters are shown in Fig.3. We point to the sharp contours of the craters as a result of brittle fractures and exclude any dissolution processes. Spallation on a smaller scale is shown in Fig.3 (thin section) and frequently occurs also on a microscopic scale [3].

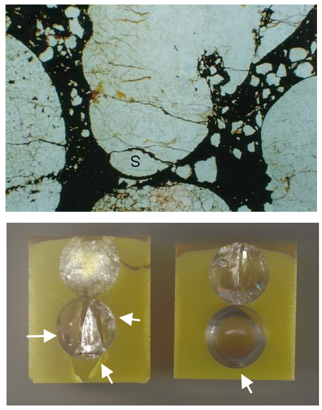

Fig.2. Sketch-map showing the location of the Azuara (A) and the Rubielos de la Cérida (R) impact structures and the investigated Buntsandstein conglomerates.

Fig.3. Photomicrograph (top; field is 6 mm wide) of a detached spall (S) in a Buntsandstein quartzite pebble, and spalls (arrows) in experimentally shocked quartz spheres (bottom, sphere diameter is 14 mm).

To investigate the conditions of spall-fracture formation in cobbles, we performed shock experiments on quartz spheres at the Fraunhofer Institute for High-Speed Dynamics in Freiburg/Germany (Fig.3). The impact velocities ranged between 25 and 115 m/s corresponding to impact initial pressures between about 0.55 and 2.5 GPa. Even at the lowest impact velocity (25 m/s), we observe clear spall fracturing in the spheres, and at higher impact velocities, up to five spalls were observed to occur in one sphere together with strong deformations described in more detail in [3].

Conclusions. - The Triassic Buntsandstein conglomerates in northeastern Spain display clear and frequent spallation effects resulting from dynamic deformations well known in fracture mechanics. Because of the vicinity of the exposed conglomerates to the Azuara impact structure and the newly suggested Rubielos de la Cérida companion crater, the spallation is ascribed to shock waves from these impact structures having led to internal accelerations within the conglomerates, multiple collisions of the components, strong reverberations, and, by focussing effects in the spherical bodies, to high compressive and tensile stresses even at very low impact velocities.

Therefore, spallation features in conglomerates are suggested as a strong macroscopic diagnostic tool to identify nearby impact sites where other signature is weak or absent.

References. - [1] Ernstson, K. et al., *this workshop*; [2] Hradil, K. et al., *this workshop*. [3] Ernstson, K. et al., Geology, v. 29, No. 1, pp. 11–14.