Evidence of meteorite impact in the Siljan structure, Central Sweden

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Within the Siljan structure, Central Sweden, shock phenomena are found: shatter cones in the granites of the core and deformed fossils within shales of the peripheral ring of Palæozoic strata. This supports the interpretation of formation of the structure by meteorite impact.

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Shatter cones in granite

— By Per Thorslund

Shatter cones, characteristic of structures interpreted as astroblemes were first found within the Siljan structure in 1970, as reported by N. B. Svensson. The first cones were observed on the road south of the small tarn Hättjärn in the central part of the structure (loc. 3, Fig. 1, Svensson 1973).

At this and other outcrops along the road, the bedrock surface had been exposed in connection with road workings, the overlying till being removed over a large area and being used as road metal. Within this area is found a small hillock composed of medium-grained granite, deeply weathered, showing a surface with well developed shatter cones (Fig. 1). This hillock with its cones now has a preservation order, the first of its kind in Sweden.

Fig. 2 is a photograph of a specimen of coarse granite from Ingärdningsbo, 8 km south of the Hättjärn locality (loc. 5, Svensson). This specimen, found in 1971 by Dr. E. Chao (U.S. Geological Survey, Washington) was presented by him to the museum of "Rättviks natur" at Rättvik. I was informed by Dr. Chao that he had never before seen such well developed shatter cones in such a coarse-grained granite.

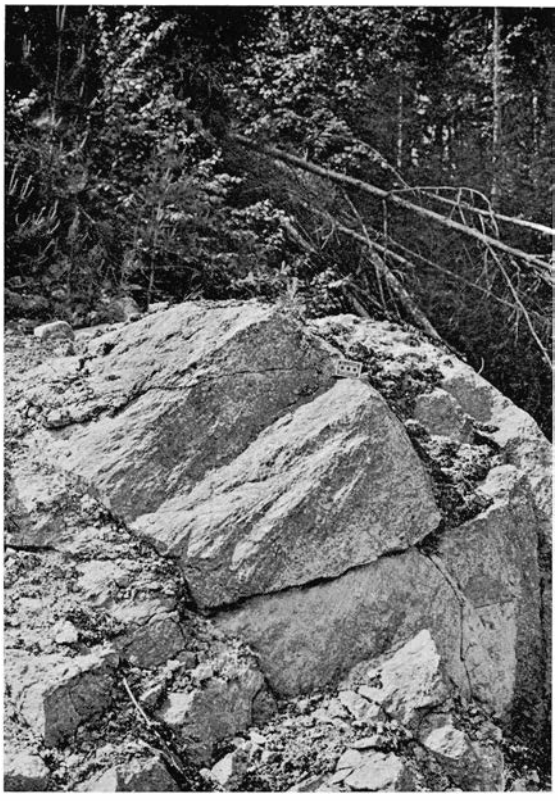

Fig. 1. The granitic hillock with shatter cones at Hättjärn. Photo Christer Larsen, Rättvik.

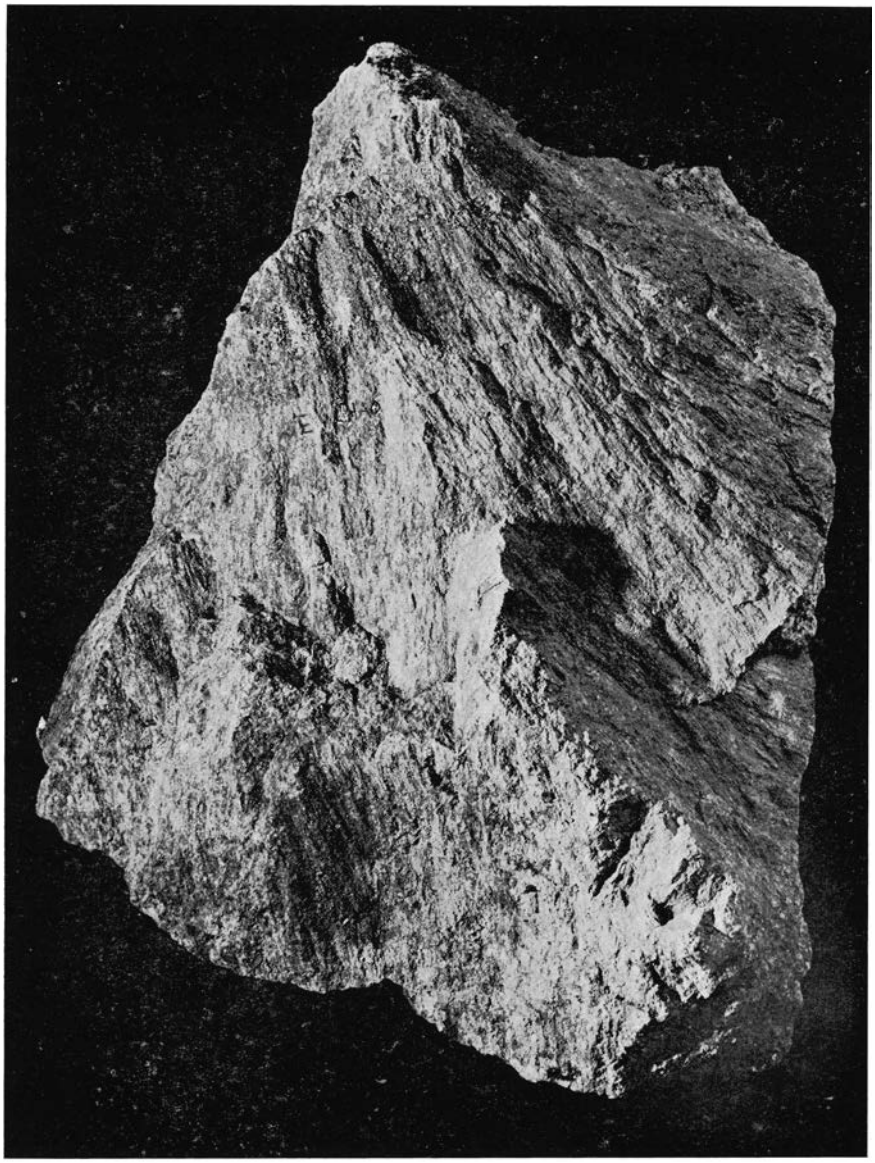

Fig. 2. Shatter cones in coarse granite from Ingärdningsbo. × 0,45. Coll. E. Chao. K. E. Foto, Rättvik.

Loose boulders containing shocked fossils
— By Per Thorslund

The flank deposits of the Boda reef limestone at Osmundsberg, 20 km north of Rättvik, consist of bedded crinoidal biosparite with intercalations of marly shales. These steeply dipping flank beds have been exposed for some years in the north-eastern part of Osmundsberg quarry. Stratigraphically these beds represent part of the Upper Ordovician sequence above the dark Fjecka Shales, i.e. the zone of *Pleurograptus linearis*. Many of the marly beds are highly fossiliferous containing brachiopods, cystoids, bryozoa, tetracorals, tabulates etc. which form a notable constituent in the talus at the base of the quarried faces.

Amongst the debris along the eastern quarry faces, many distorted fossils are found, some containing small-scale fault or thrust planes. In these specimens measurable displacement has occurred along the planes (Fig. 3). The displacements are variable but generally small; the maximum

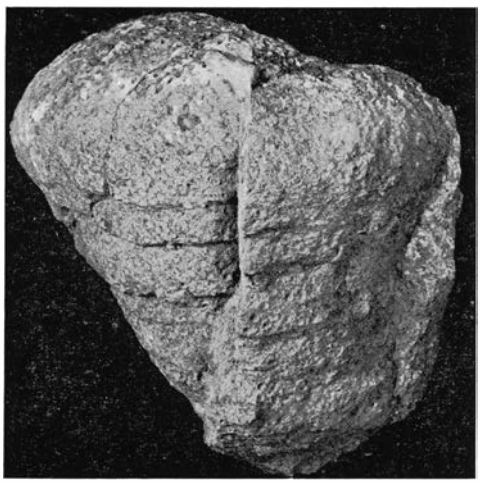

Fig. 3. A conical *Heliolites* sp. divided into two parts by a vertical fault plane. × 1/2. — From marly shales in the flank deposits of the lower part of the Boda reef at Osmundsberg. Photo G. Andersson, Uppsala.

measured being 10 mm in a large colonial Heliolitid. Occasionally fossils are cut by a series of subparallel planes as shown in the case of the small conical specimen of *Heliolites* (Fig. 4).

Shocked fossils in situ

— By Clive Auton

As a result of recent palæoecological studies of both the Boda Limestone and Kullsberg Limestone at Osmundsberg, numerous shocked fossils have been found in situ. These are most abundant in the upper half of the Boda Limestone, but occur rarely throughout the whole sequence. The best examples are large tabulate corals, some of which appear to be in life position. These are cut by thrust planes, the majority of which strike 045° & 135°, i.e. at right angles to each other and dip at angles of up to 55° towards SE and SW.

The strike of the thrust planes is coincident with that of the vertical master joints in the rock, but they can be distinguished from the joints by their lower angle of dip and by the fact that measurable displacement has occurred along each thrust.

The overlying Silurian sequence at the northern end of the quarry contains concretions of microtic limestone, many of which are also cut by low angle fault planes with the same dip and strike as those in the fossils of the reefs themselves.

Concluding remarks

The illustrations in this paper demonstrate the effect on the bedrock of the meteorite impact which formed the Siljan structure and is largely responsible for its present morphology. The shatter cones occur in the central "core" of the structure, whereas the shocked fossils are found within the peripheral circular belt of Lower Palæozoic sediments. The impact is presumed to be post-Silurian in age as the concretions within the Silurian sequence were rigid and capable of brittle deformation before the impact occurred.

The deformed specimens figured are interpreted as shocked fossils because it is evident that the deformation of the fossils is post-depositional and post-compactional as the surrounding shale is draped around individual specimens. Within the

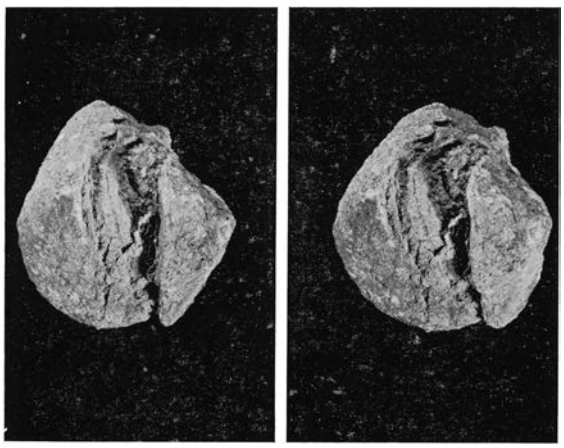

Fig. 4. A conical *Heliolites* sp. deformed by several almost parallel fault planes seen from above. × 3/4. Stereophotograph. Locality and photo as in Fig. 3.

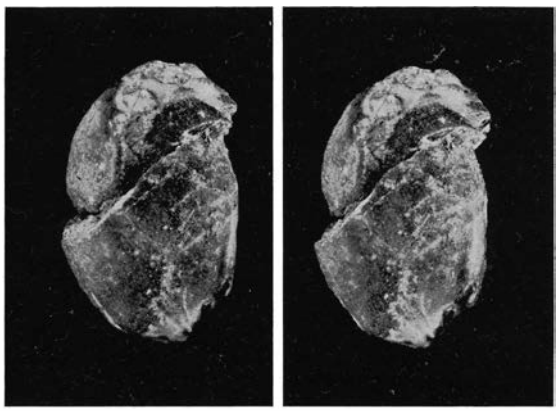

Fig. 5. Haplosphaeronis oblonga (Ang.) with a fault plane. × 4/3. Stereo. Locality and photo as in Fig. 3.

highly fossiliferous shales only forms with a certain geometric shape and orientation are affected. Delicate conical forms, such as corals, are often found to be deformed, while the abundant cystoids, notably *Haplosphæronis oblonga* (Ang), which are ellipsoidal to subspherical in shape having a comparatively thick calcareous exoskeleton, are generally undeformed. These cystoids are found generally in their most hydrodynamically stable position, i.e. the longest axis of the ellipsoid bedding parallel. However, when the cystoids are found with their longest axis in an upright position, they are often cut by thrust planes (Fig. 5).

This type of deformation of fossils, inter alia belemnitic rostra, and concretions have previously been recorded from the Ries in South Germany by Hüttner (1969, p. 163, Fig. 12) who also reports similar phenomena observed in the Steinheimer Becken.

From this it is concluded that the shock waves emanating from the impact most affected those fossils which were not aligned parallel to the bedding planes and which are angular rather than rounded in outline.

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