THE AZUARA AND RUBIELOS STRUCTURES, SPAIN: TWIN IMPACT CRATERS OR ALPINE THRUST SYSTEMS? TEM INVESTIGATIONS ON DEFORMED QUARTZ DISPROVE SHOCK ORIGIN; F. Langenhorst¹ and A. Deutsch²; ¹Institut für Mineralogie, Museum für Naturkunde, Humboldt-Universität Berlin, Invalidenstr. 43, D-10115 Berlin, Germany; ²Institut für Planetologie, Universität Münster, Wilhelm-Klemm-Str. 10, D-48149 Münster, Germany.

Summary. The origin of the Azuara structure, NE Spain, is controversially discussed. It is interpreted as either an impact crater or Alpine thrust system. Recently, it has been suggested that Azuara has a twin impact crater: Rubielos. TEM analyses on quartz grains from quarzites of the Azuara and Rubielos areas, which have been described to contain shock features, only reveal a large density of dislocations and many sub-grain boundaries; planar deformation features are absent. This result does not disprove an impact origin for Azuara and Rubielos; unambiguous signs of shock metamorphism, however, are not yet known from these regions.

Introduction. The Azuara structure some 50 km south of Zaragoza (N 41°10'; W 0°55') is interpreted either as 35 - 40 km wide impact crater [1 - 4] or Alpine thrust system [5]. The presence of monomict and polymict breccias, breccia dikes, a gravity anomaly, kink bands in biotite, mosaicism and optical features in quartz resembling planar deformation features (PDFs [6]) has been used in support of the impact origin; Azuara is listed in the table of "known terrestrial impact structures" [7]. Similar characteristics have recently also been described for the near-by (100 km south of Zaragoza) Rubielos structure, which thus has been interpreted as impact crater, as well [8, 9]. The listed characteristics of rocks and minerals from Azuara and Rubielos, however, except the apparent "PDFs" in quartz could also result from tectonic and/or sedimentary processes known to have taken place in the Iberian chain and its foreland basins [5]. Hence, confirmation of the occurrence of "PDFs" stands as the critical argument for the impact hypothesis.

Results and discussion. To test whether the previously observed optical features [3, 8, 9] indeed represent shock-produced PDFs, three quartzite samples (PF12, EP2b, and LY3) provided by Dr. K. Ernstson have been carefully re-investigated by applying optical and transmission electron microscopy. Sample PF12 is a quarzite clast from the Pelarda Formation, assumed to be a remnant of the Azuara ejecta blanket [3]. EP2b and LY3 are quartzites from autochthonous lithologies of the Rubielos structure.

Optical examination revealed that quartz grains from all samples display undulatory extinction instead of mosaicism. The optical features in quartz are rather curved than planar (Fig. 1), and sometimes decorated with tiny vugs. In this respect they resemble decorated PDFs but, in contrast to earlier observations [1], they are not oriented parallel to any rational crystallographic plane, especially not parallel to the typical PDF planes (1013) or (1012), cf. [6, 10]. Single sets of these subparallel optical features occur in PF12 and EP2b (Fig. 1), whereas, some quartz grains in LY3 contain also crossing sets. The typical spacing between optical features is about 5 - 10 μm, exceeding slightly the typical spacing of PDFs [5, 6, 10].

TEM observations of quartz grains with the above described optical features yield two microstructural characteristics: (a) A large density of dislocations and (b) many sub-grain boundaries (Fig. 2). It is well-known from TEM investigations on experimentally and naturally shocked quartz [6] that dislocations cannot be activated during dynamic shock compression;
only tectonic deformation can account for this deformation behaviour known as "hydrolytic weakening". During this process, dislocations are partially reorganised in the form of sub-grain boundaries in order to minimise the internal energy of the quartz crystals. Such sub-grain boundaries cause the optical contrast misinterpreted by [3, 8, 9] as real PDFs, which are in their fresh form amorphous lamellae [6]. The formation of sub-grain boundaries has probably been assisted by the elevated temperatures associated with the tectonic event.

**Outlook.** The results of this survey study re-open the question whether the Azuara and Rubielos structures are really impact craters. In any case, the quartz grains examined by TEM unambiguously do not record any shock metamorphic overprint and, hence, cannot be used as argument for proving the impact hypothesis. Moreover, our data demonstrate that in doubtful cases of optically characterised "planar elements or planar deformation features", only TEM provides the conclusive answer for the real type of deformation.

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