Shock metamorphism in the Rubielos de la Cérida impact basin (Eocene-Oligocene Azuara multiple impact event, Spain) - reappraisal and photomicrograph image gallery

by Kord Ernstson[1] and Ferran Claudin[2] (April 2021)

Abstract. - We present a new compilation of previously abundantly studied and published shock effects in minerals and rocks of the Middle Tertiary Rubielos de la Cérida Impact Basin in northeastern Spain. Typologically, we organize by: shock melt - accretionary lapilli - diaplectic glass - planar deformation features (PDF) - deformation lamellae in quartz - isotropic twins in feldspar - kink banding in mica and quartz - micro-twinning in calcite - shock spallation. Included are the newly associated Jiloca-Singra impact in the so-called Jiloca graben and the Torrecilla ring structure, which immediately adjoins the Rubielos de la Cérida basin to the northeast. The compilation and presentation also opposes once more the still existing fundamental rejection of an impact genesis of the Azuara impact event by leading impact researchers of the so-called impact community and by regional geologists from the University of Zaragoza.

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1 Introduction

Rubielos de la Cérida (Fig. 1 -3) is still hushed up by the so-called impact community of a few researchers (e.g. French and Koeberl 2010, Reimold et al. 2014, Spray, written communication, Schmieder and Kring 2020) despite the extensive documentation of all impact-relevant finds and findings (a compilation see e.g. here: Ernstson and Claudin 2021). In these past 20 years, a lot of new findings and insights have accumulated, and some of them may have been forgotten in the confusion of various publications and internet sites. As particularly significant for the proof of an impact genesis, mineral and rock changes of a shock metamorphism are still considered rightly, which occur extremely richly with the Azuara impact event and above all in the Rubielos de la Cérida impact basin.

Fig. 1. Location map for the Azuara and Rubielos de la Cérida impacts.

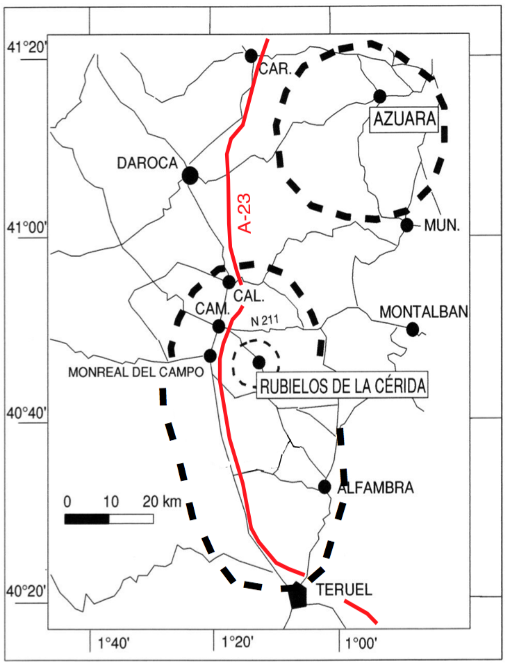

Fig. 2. Map for general orientation in the multiple impact field of the Azuara impact structure and the Rubielos de la Cérida impact basin. CAL. = Calamocha, CAM = Caminre-al, CAR = Cariñna, MUN = Muniesa; A-23 = Autovía Mudéjar.

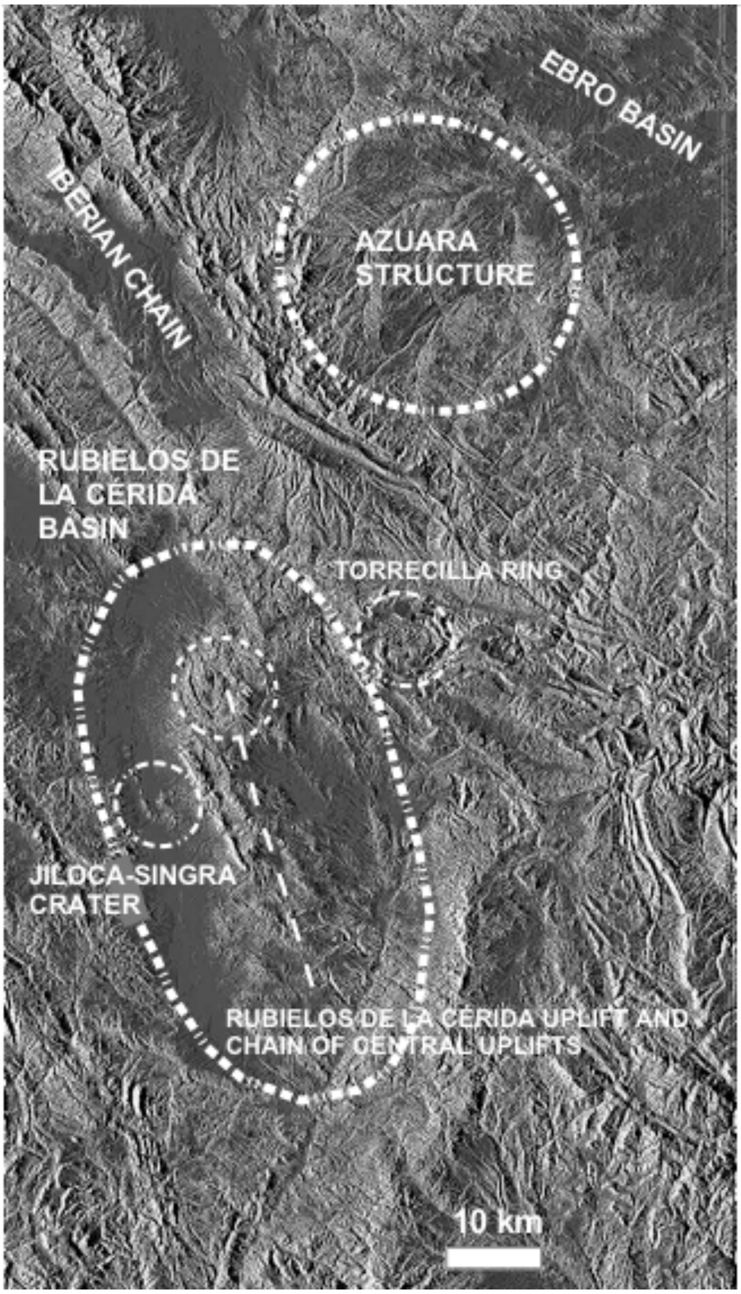

Fig. 3. Digital map 1 : 250,000 of the Azuara multiple im-pact event, which produced a crater chain of about 120 km length.

From a review of previous scattered published and unpublished findings, we have assembled here a typologically organized gallery of shock effects, which has three objectives: It should be a kind of teaching material for all those geologists, but also mineralogists, who have had difficulties with impact and its phenomena, especially in view of the fact that the presented shock effects are all in sedimentary rocks and partly very unusual and largely unknown formations. Furthermore, all amateur impact researchers are addressed, from whom very valuable contributions to impact research are made again and again.

As a second reason we attempt to make the mentioned impact researchers (and those who uncritically let themselves be "infected" by it) to end their absurd, science killing insistence on the silence and the rejection of the Azuara/Rubielos de la Cérida impact.

A third aspect focuses on Spanish geologist in particular from the Zaragoza university, who completely ignore impact genesis and effects in a significant part of the Tertiary Iberian System, almost maliciously conceal the extensive literature on the Spanish impacts of Azuara and Rubielos de la Cérida against all scientific rules, and still steadfastly adhere to their old, long-disproved models. Only recently, as in an article on the Jiloca graben (Ernstson and Claudin 2020), we have shown geologically irrefutably that the entire ideas of the Spanish geologists dealing with the region completely miss the geological reality. They are basing their ideas and models on erroneous mapping and seeing the proven big impact as non-existent. This includes the recent work of Simón et al. (2021) on the Daroca thrusting, which has recently become a remarkable recurrent focus of Zaragoza geologists, after we provided undoubted evidence of the Azuara impact process in the formation of the prominent Daroca thrusting a few years ago (Claudin and Ernstson 2012, 2020 a, b), relegating all other Zaragoza regional geological explanations and models to the realm of fable.

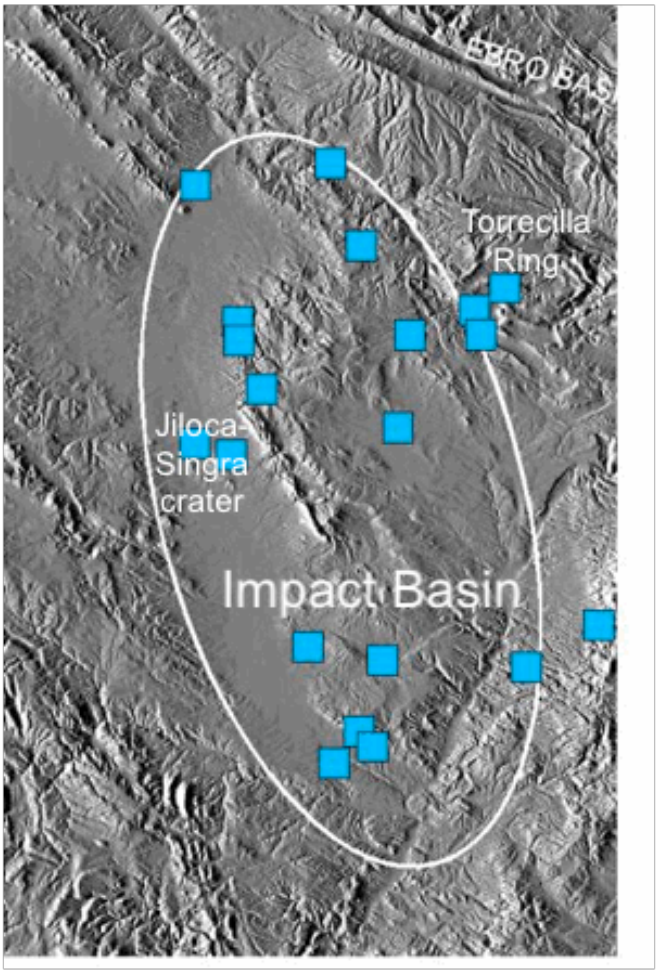

Fig. 4. Digital Terrain Model of the Rubielos de la Cérida impact basin and locations where shock metamorphism has so fas been established.

2 The compilation of shock metamorphism (Fig. 4) in the Rubielos de la Cérida impact basin.

In the following gallery of SEM and optical images, as well as of the vast majority of photomicrographs, we organize them into typologically related complexes, each with brief captions and, where applicable, links to more detailed characterization.

A note should already stand here in relation to the Shock Melt complex. Impact melt and impact glass are not only produced by the extreme temperatures during shock pressure release but can also be the result of frictional heat during the partly gigantic movements under extreme pressure and at high speed in the impact phases of excavation and ejection as well as modification. If no cogenetic accompanying shock effects are detectable, an exact address must remain open, provided that the geological finding situation does not speak for one or the other.

Without doubt a very special shock effect in the Azuara impact event and also widespread in the Rubielos de la Cérida impact basin are accretionary lapilli, mostly in suevites of the basal breccia, but in many cases also as pure lapillistones. In the absence of volcanism, from which accretionary lapilli are otherwise known to geologists, these very special and typical formations are now also described from a number of impact structures, where they can logically form in the massive explosion cloud.

An at least theoretical restriction is to be made with the shock effect of bent mica. Kink bands in mica can also develop under extreme tectonic pressures of a regional metamorphism. However, if crossing sets of kink bands with extreme kink band frequency are observed, as is regularly the case in the Spanish impacts, tectonic stress can reasonably be excluded and a true shock effect diagnosed, in particular if kink banding of mica occurs in otherwise shocked rocks. Similar considerations apply to kink banding in quartz, which occurs here in sometimes spectacular form.

A very special form of shock effects, which has not been recognized as such by impact research at all, are abundant open spallation fissures in quartz grains, for whose open wide tensile cracks, purely physically, no other interpretation possibility remains than that of a shock spallation (Ernstson 2014).

3 Conclusion

The conclusion is anticipated here before the extensive compilation of virtually all known strong and moderate shock effects in meteoritic impacts follows. This evidence is not found in a few hand pieces, but widely scattered over a vast area of about 80 km x 40 km. The operators of the Canadian Earth Impact Database under the leadership of John Spray, for which the multiple Azuara impact event with the Azuara impact structure and the Rubielos de la Cérida impact basin still does not exist at all, are reminded that the published impact findings of geology, geophysics, petrography, mineralogy, and geochemistry at Azuara and Rubielos de la Cérida exceed in richness and significance, with extremely good terrain accessibility, the vast majority (perhaps more than 90%) of all impact structures listed as established in the database. In its singularity as a multiple impact with Azuara and the stringed Rubielos de la Cérida crater chain there is no equal on Earth. This is a scientific absurdity for impact research when a few leading people in the "impact community" articulate their personal aversions in this way.

That this obviously has not remained without effect is shown especially by the behavior of Spanish geologists, in particular the regional geologists of the University of Zaragoza, who can refer to this non-existence in the Canadian database and who stick to their long since thoroughly disproved textbook graben-basin models of the Iberian System and publish it as they have done for 20 years and more and up to the present day (e.g., Simón et al. 2021). One can only advise them: Closing their eyes does not eliminate the great Spanish impact.

References

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Simón, J.L., Casas-Sainz, A.M., Gil-Imazes, A. (2021) ReferencControversial epiglyptic thrust sheets: The case of the Daroca Thrust (Iberian Chain, Spain). - J. Structural Geology, 145 (2021) 104298.

APPENDIX: GALLERY

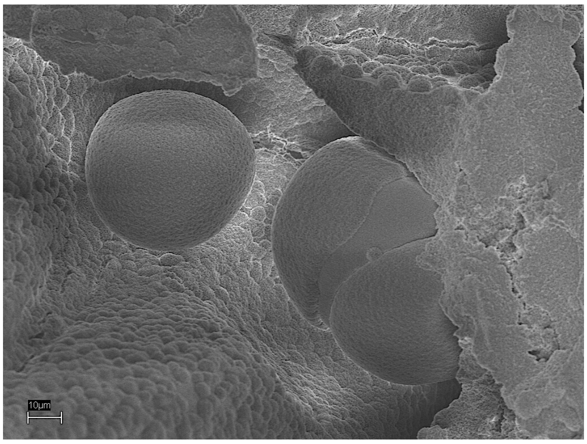
Shock melt

Silicate melt

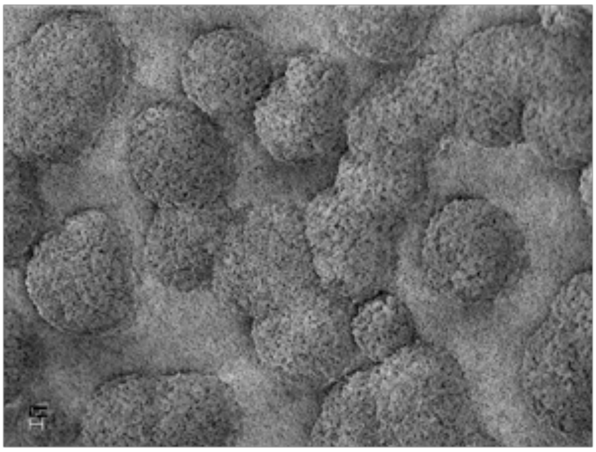
Patches of silicate melt in Lower Tertiary claystones. Barrachina megabreccia.

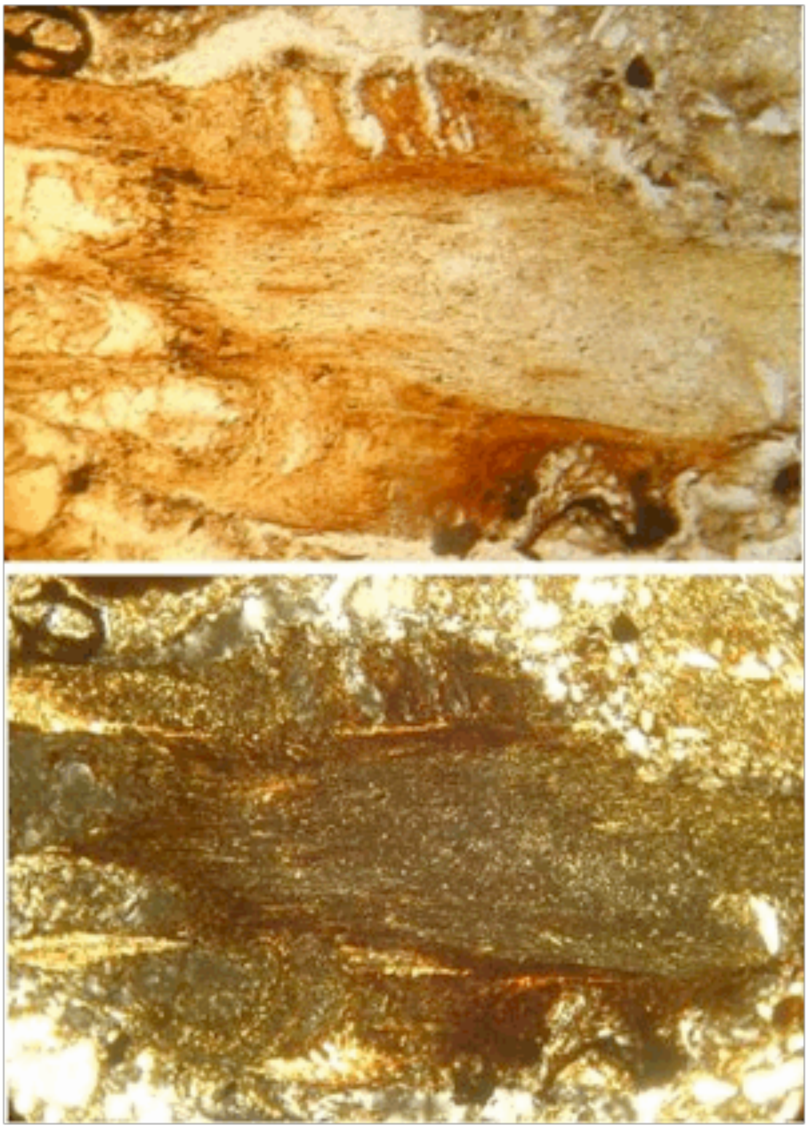
Ribbon of silicate melt in the Barrachina megabreccia. - Spanish geologists, confronted with the for them completely unexpected melt rock composed of 90% glass with clay-shale chemism in this stratification, did not know how to help themselves other than to declare it as volcanic ash, without explaining where this "ash" should have come from at this place.

Silicate shock melt rock, >90% pure glass from melted shale; Barrachina megabreccia. Optical microscope; field width 15 mm.



SEM images taken from the impact glass above (shock-melted shale); Barrachina megabreccia. Scale bar to the right 10 µm.

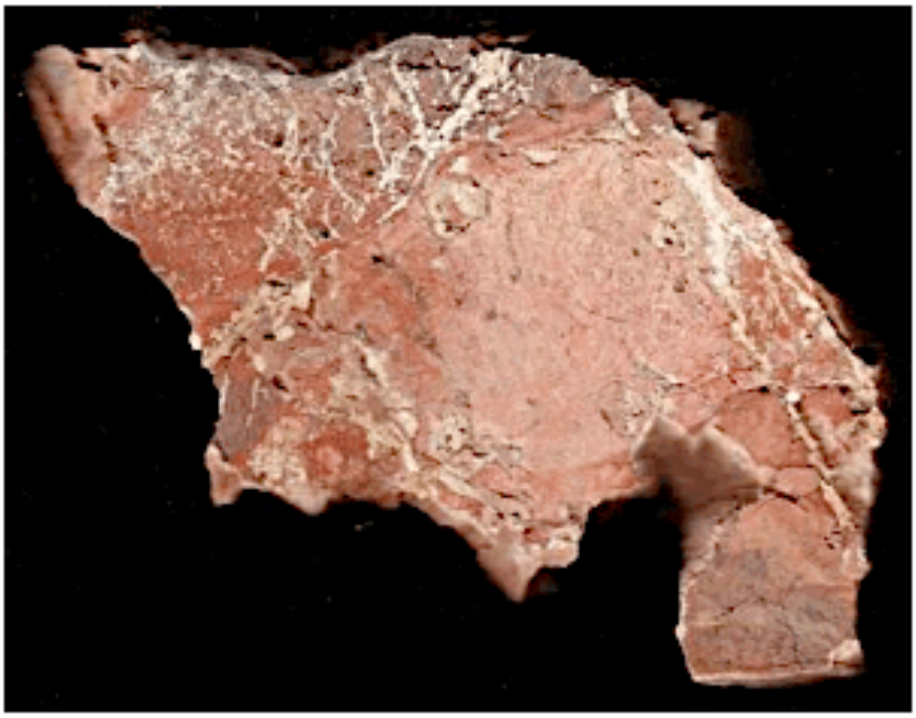

The silicate melt rock under the SEM. 1 µm scale bar. SEM Images: ZEISS.



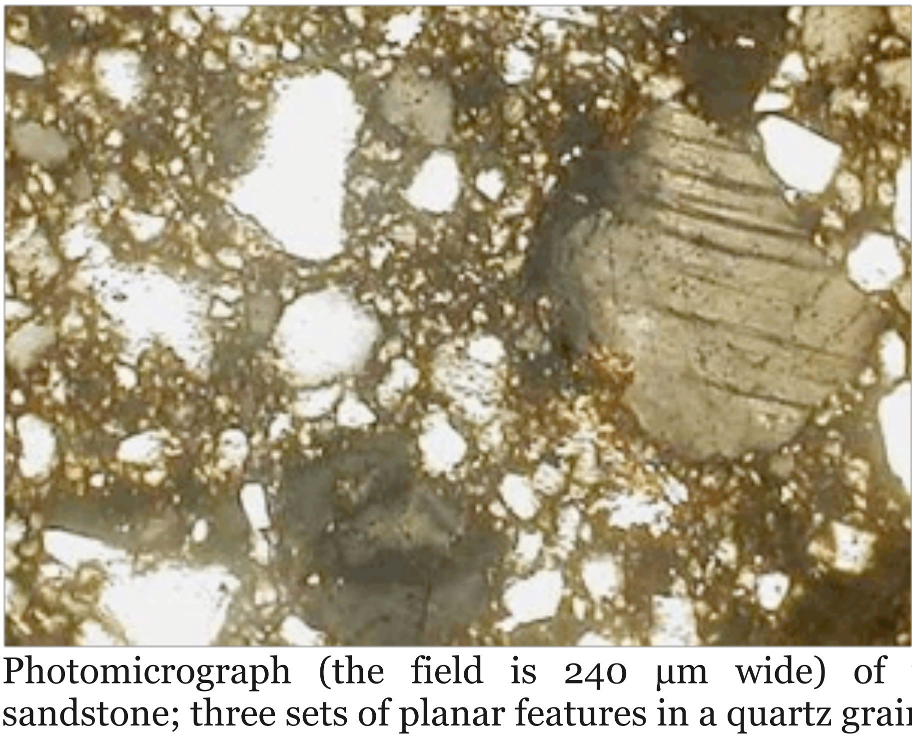
Melt glass, PPL and XX. Suevite from the Barrachina megabreccia.

Shock-produced or pseudotachylite(?) glass coating a sandstone in the southern uplift chain near Caudé.

The glass in close-up.



The glass-bearing sandstone cut perpendicularly to the glass crust (in the upper part). The field is 16 cm wide.



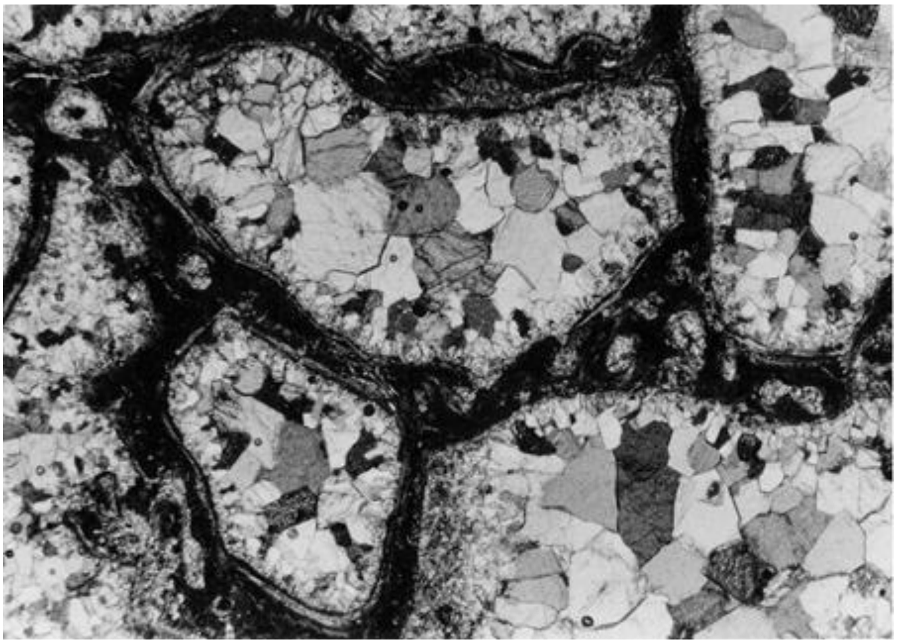
Photomicrograph (the field is 240 μm wide) of the glass-bearing sandstone; three sets of planar features in a quartz grain.

Carbonate-phosphate melt

Clast of carbonate-phosphate melt rock (white) in the Barrachina megabreccia. Coin diameter 23 mm.

Carbonate-phosphate melt: surface of a break.

Carbonate-phosphate melt in close-up: Calcite amoebic bodies (darker) in a matrix of phosphate glass (white). The field is 30 mm wide.



Carbonate-phosphate melt rock: Photomicrograph (crossed polarizers) of amoebae-like calcite bodies within a matrix of phosphate glass (dark). Note that the size of the individual calcite crystals increases towards the centers of the bodies. Also note that the peripheral calcite obviously has grown perpendicular to the rim because of the orientation. In part, especially along the borders to the calcite bodies, the phosphate glass has recrystallized to form apatite (elongated, sometimes flaser-like minerals tangentially orientated to the calcite bodies). The field is 6 mm wide.

Sulfate melt rock

Clast of sulfate melt rock in the Barrachina megabreccia. Coin for scale.

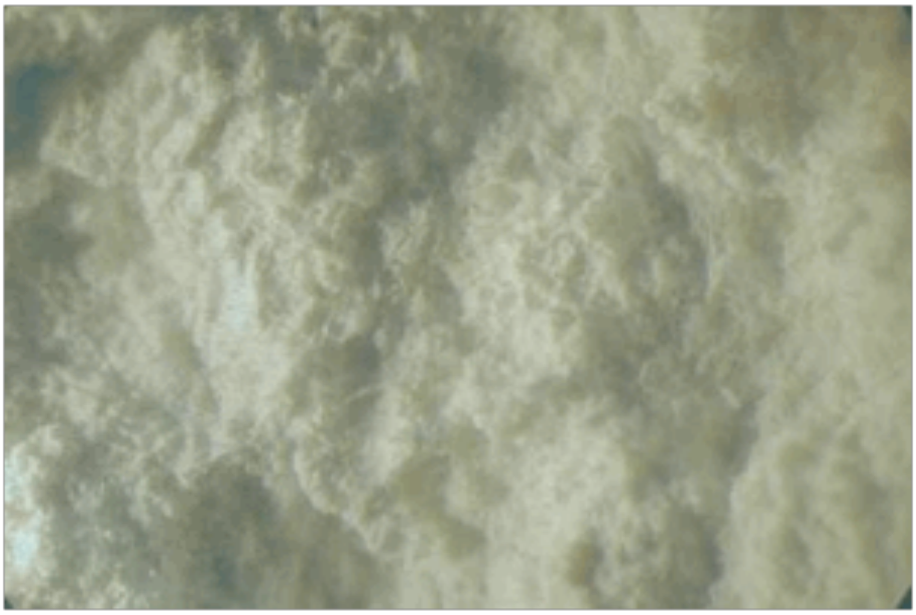
The sulfate melt rock in close up. Note the quartzite clasts in the low-density, highly porous $CaSO_4$ matrix.

The sulfate melt rock under the SEM. Note the vesicular texture.

Carbonate melt rocks

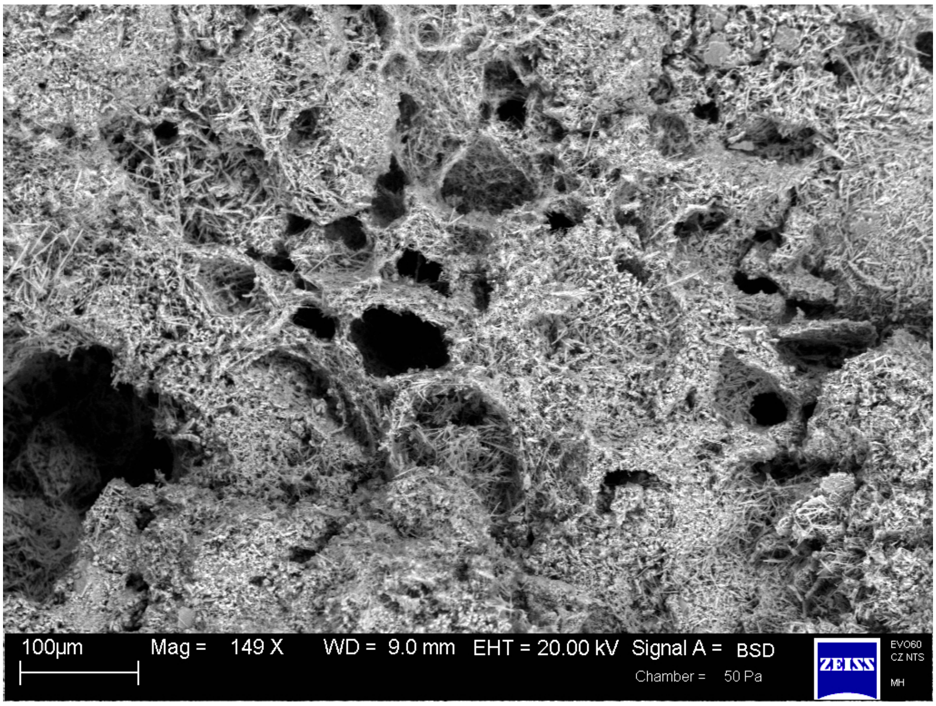

Carbonate melt rock dike cutting through Jurassic limestone.

Carbonate melt rock from the Corbalán limestone quarry, southern impact basin. Close-up below.

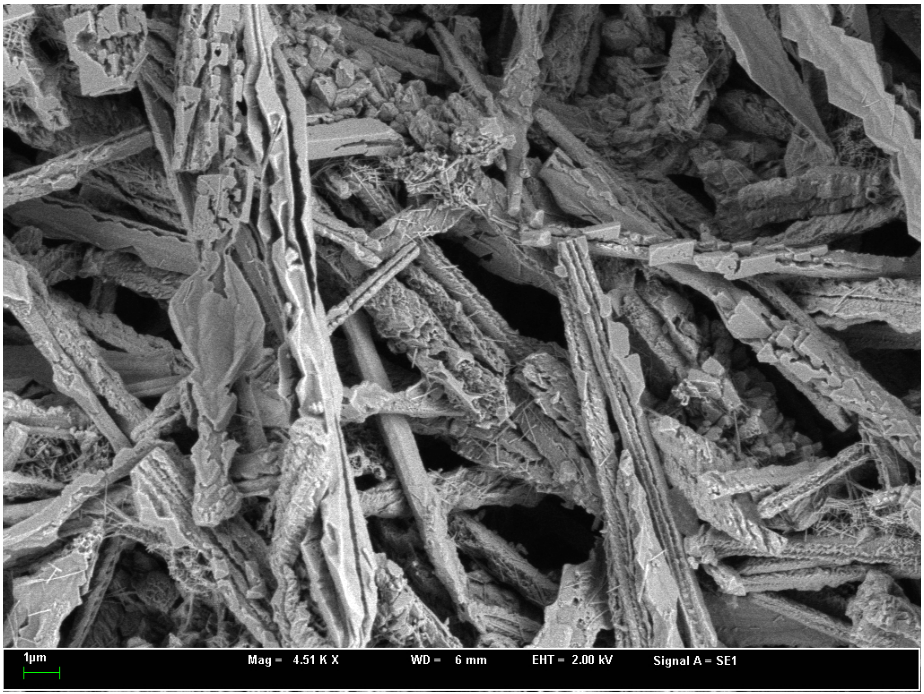


The low-density, highly porous material shows a distinct vesicular texture (the field is 7 mm wide).

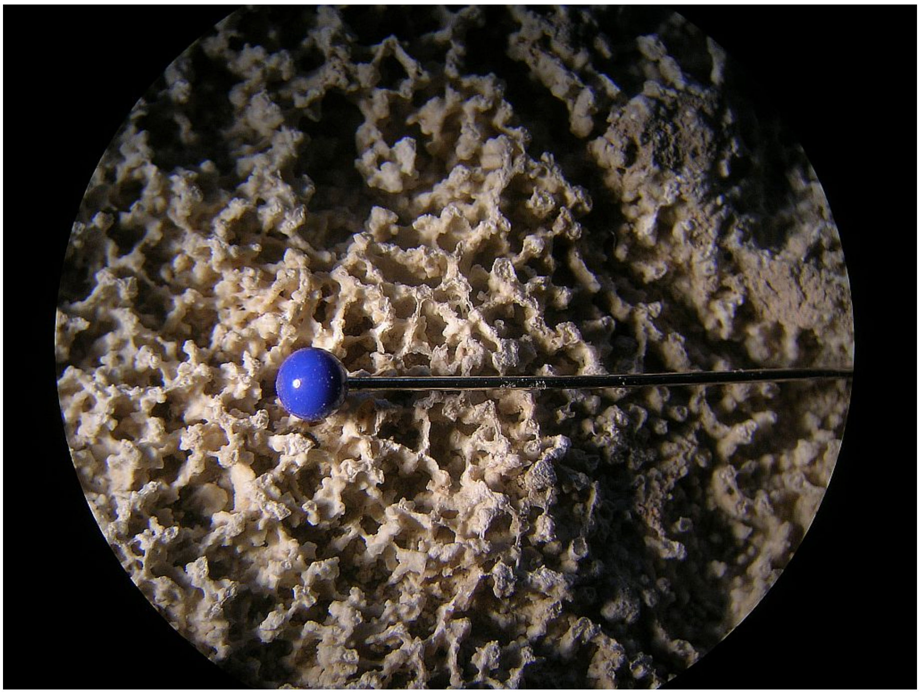
White relics of carbonate melt coating a disintegrated, decarbonized vesicular limestone. Megabreccia between Escorihuela and El Pobo/Corbalán; southeastern rim of the impact basin.



SEM image of the relics of carbonate melt; basin rim between Escorihuela and El Pobo. Note the vesicular felted texture.



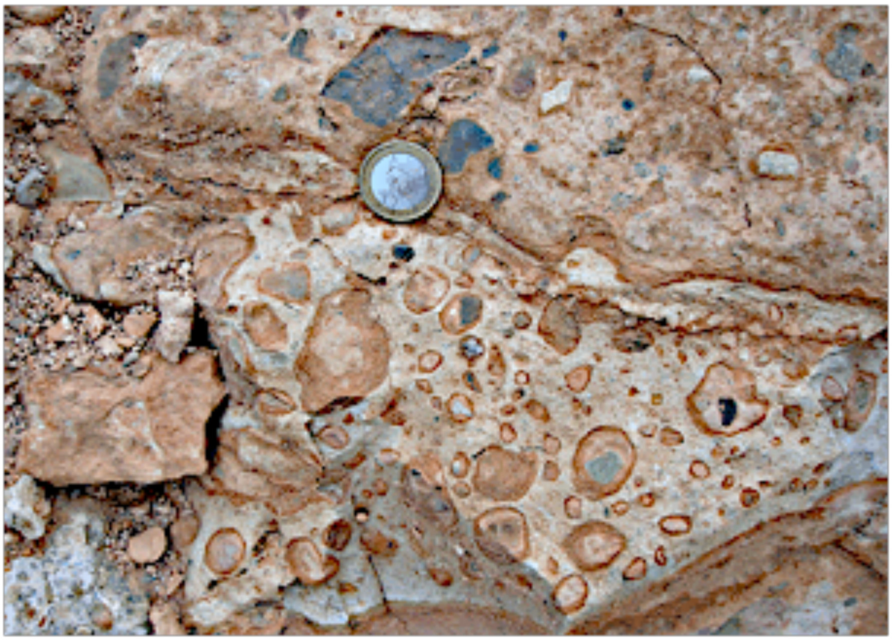
SEM image of the relics of carbonate melt, formerly probably Muschelkalk limestone. Note the dendritic crystallites (field width 25 µm).



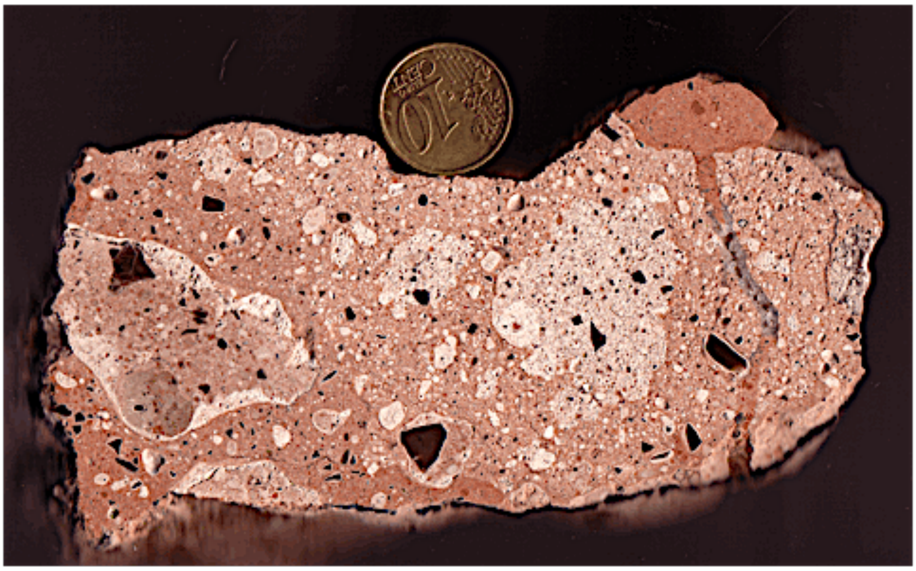
Relics of carbonate melt. Torrecilla ring structure.

Accretionary lapilli

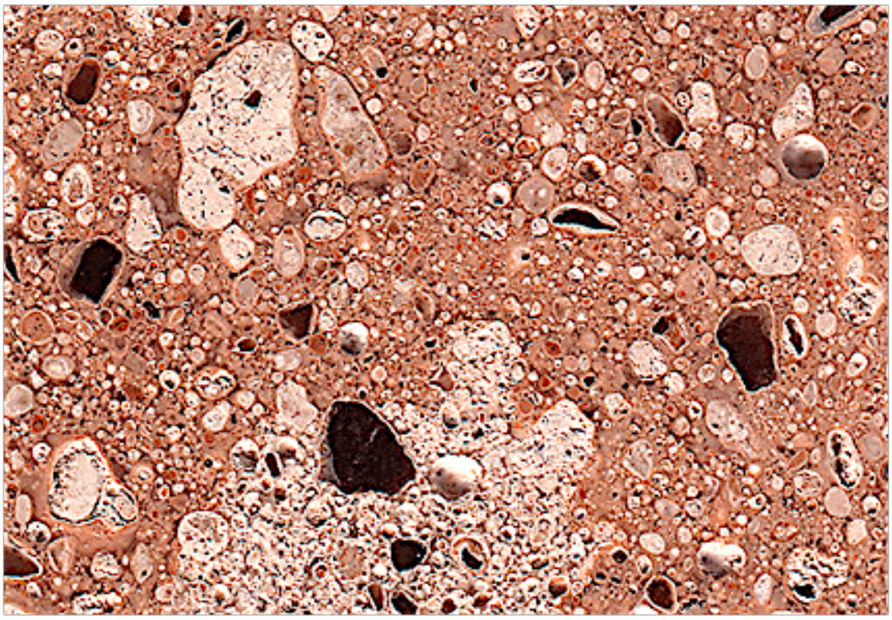
System of dikes composed of accretionary lapilli in a light-colored matrix is cutting through the basal suevite breccia near Fuentes Calientes, eastern basin region.



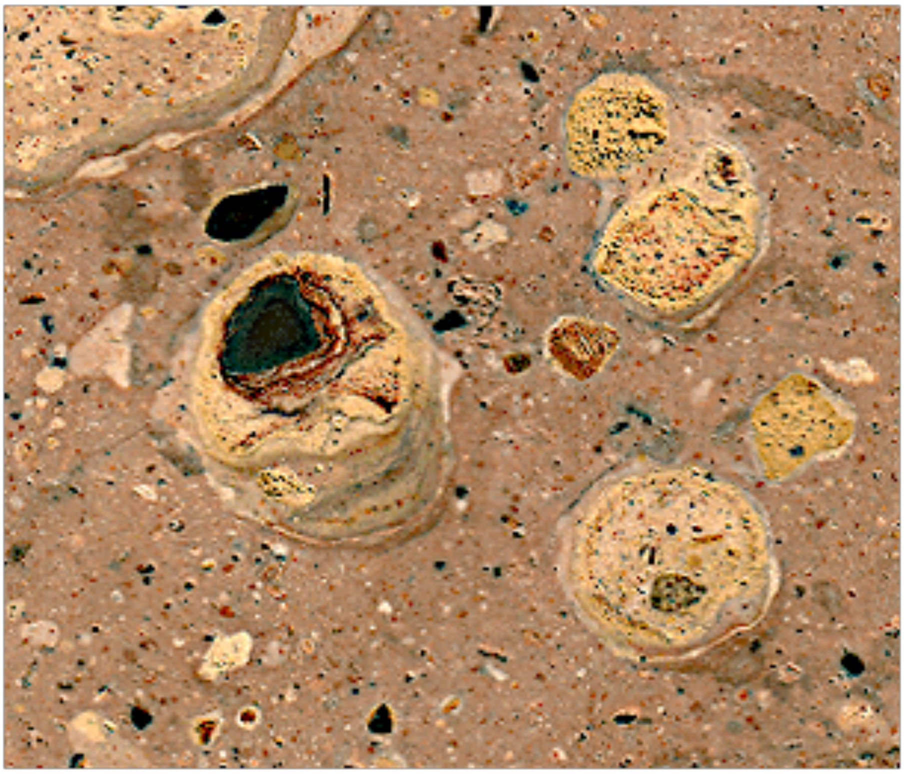
Close-up of the lapilli-bearing dike penetrating the basal breccia near Fuentes Calientes. Note that many lapilli have the typical onion skin structure around a stony core.



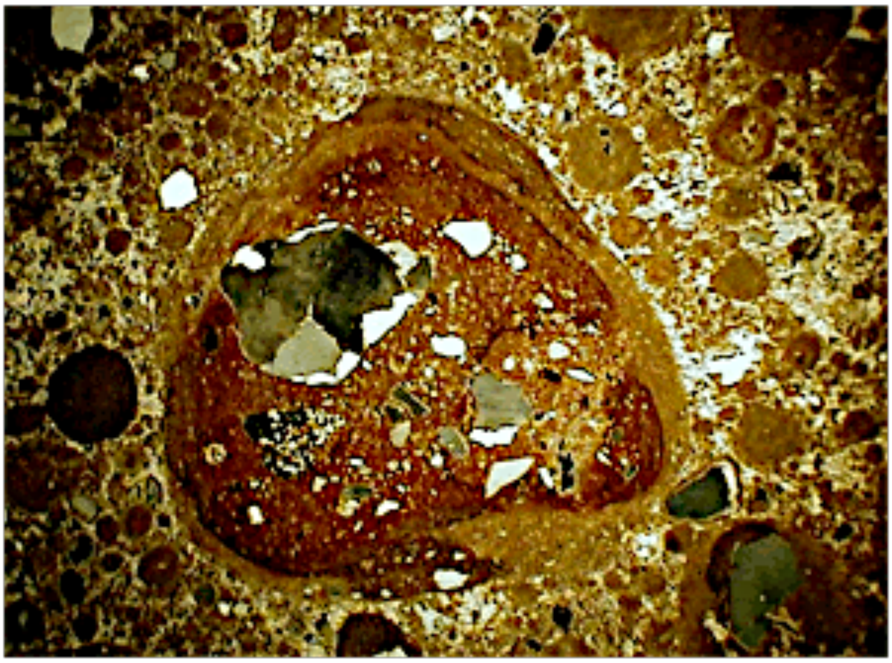
Large parts of the basal breccia outcropping near Escriche in the southern part of the impact basin are composed of a lapillistone matrix with only few sharp-edged rock fragments, probably Muschelkalk limestone. Note that the sample shown here has the character of a matrix-within-matrix texture. Also note the matrix dike in the right part penetrating the afore formed matrix giving evidence of a very peculiar lithification.



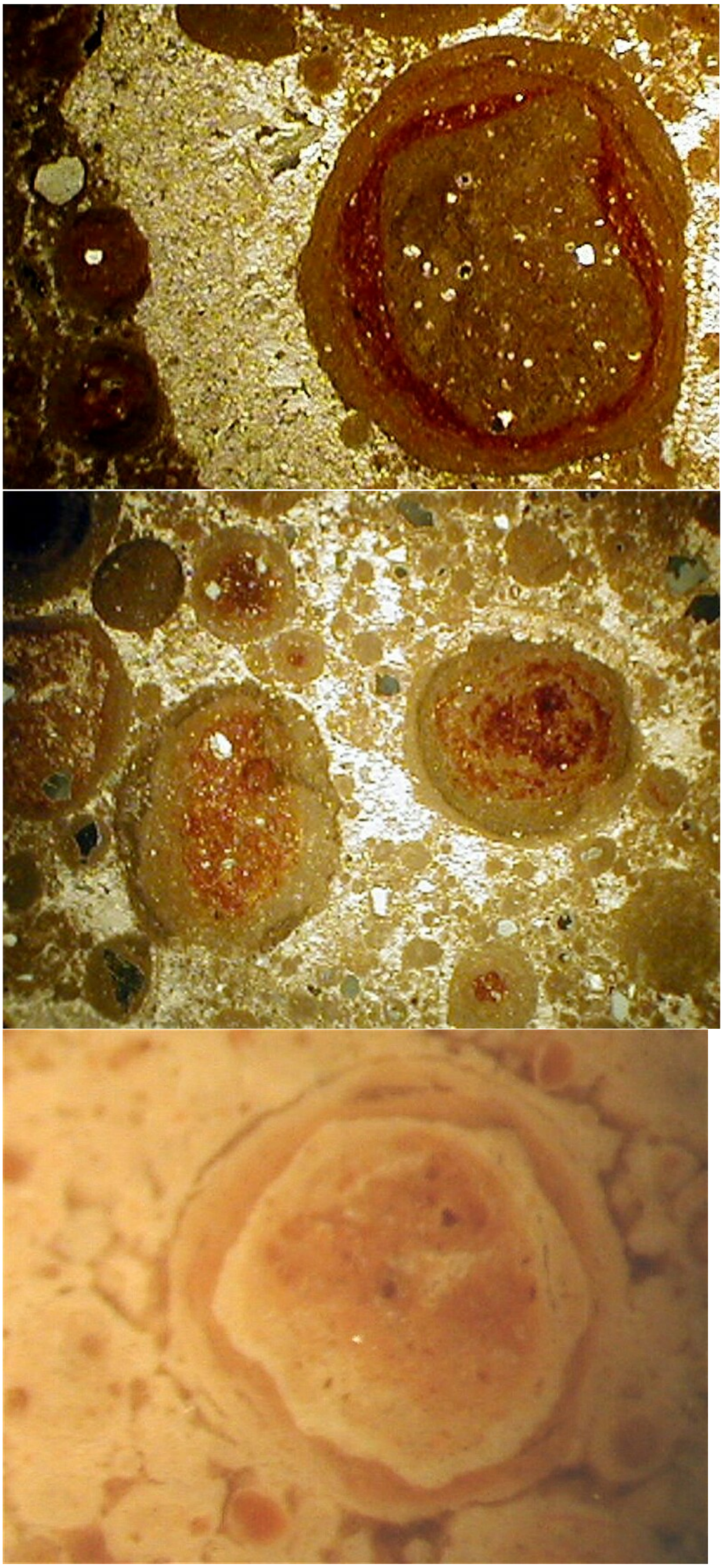
Close-up of the lapilli breccia exposed near Escriche. The field is 18 mm wide.



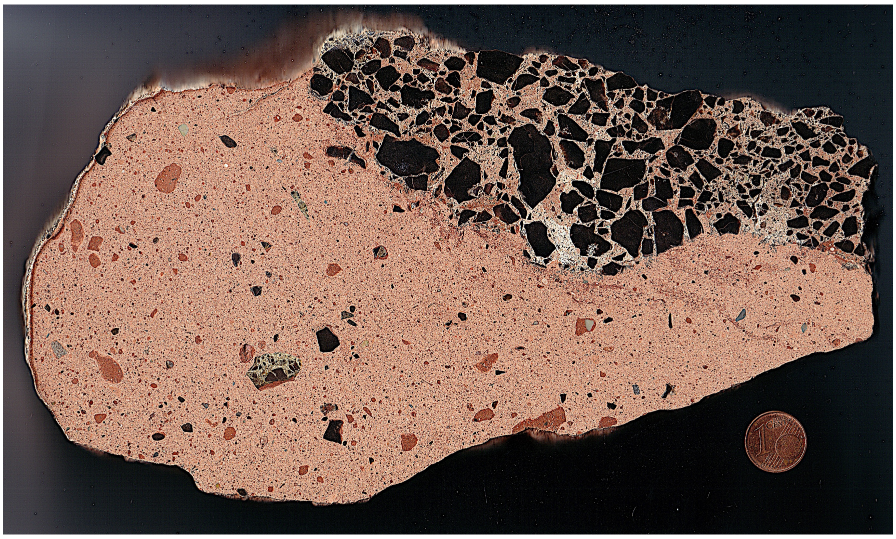
Accretionary lapilli in the matrix of the basal suevite breccia from near Corbatón, east of the Rubielos de la Cérida central uplift. Field width 3 cm.



Accretionary lapilli from the Corbatón basal breccia in thin section. Photomicrograph, xx polarizers, field width 6.5 mm. The lapilli are basically carbonate with some accessory silicate material (e.g., quartz fragments in the large lapillo).

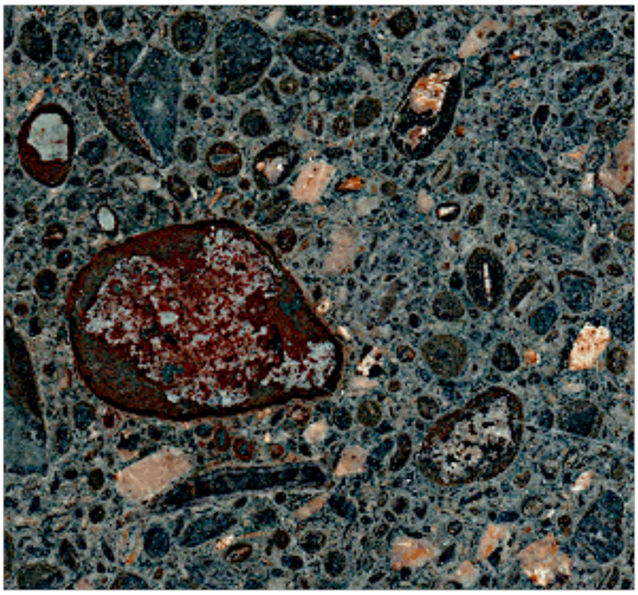


More accretionary lapilli from the Corbatón basal suevite breccia.



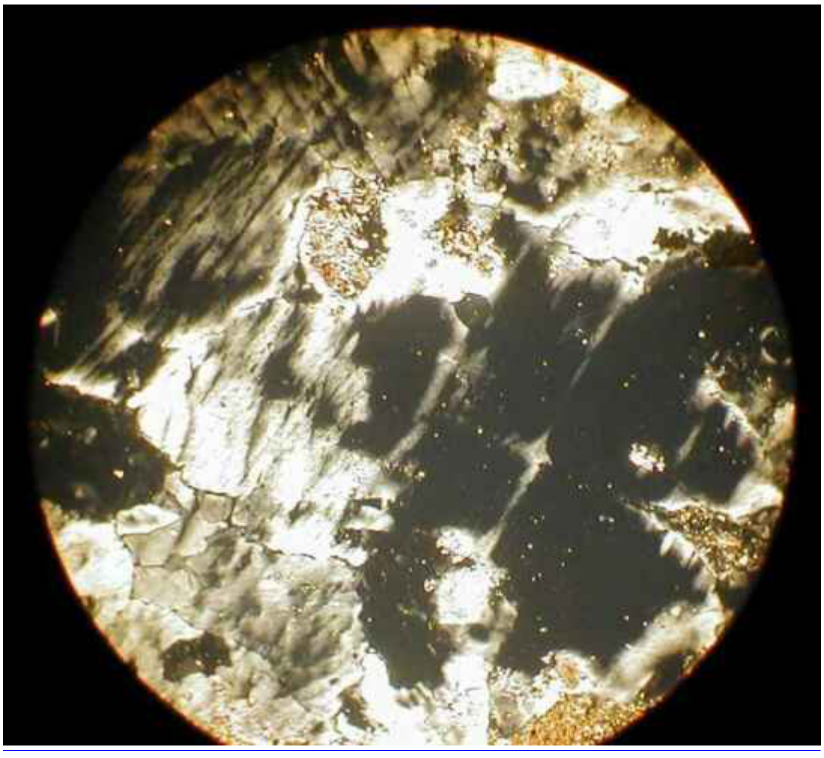
Muschelkalk breccia-within-breccia in lapillistone matrix (accretionary lapilli) near Olalla.

Close-up of the lapillistone matrix

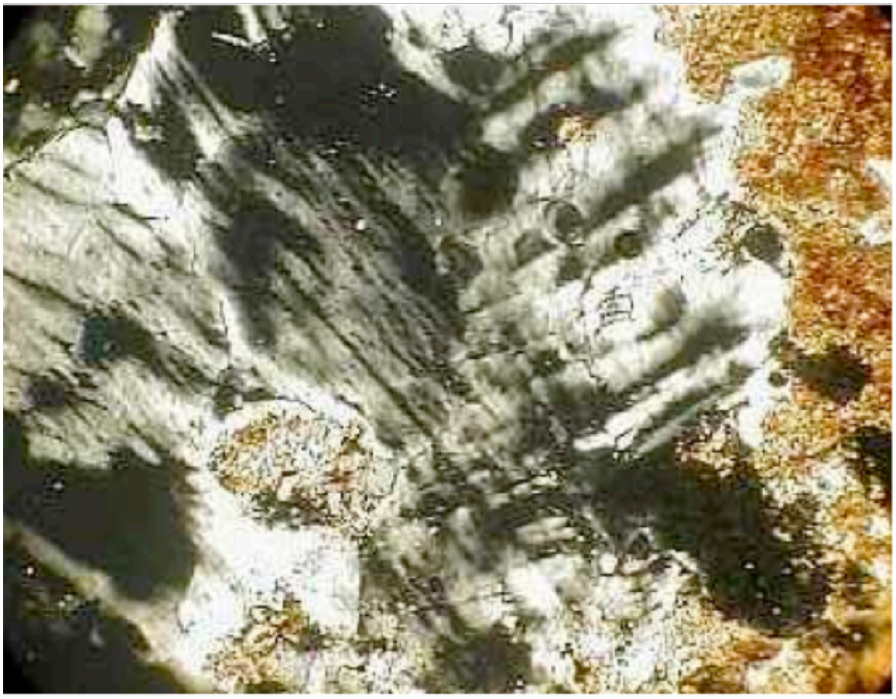


For comparison: lapillistone from a volcanic diatreme. Sawed and polished sample of accretionary lapilli in the Avon kimberlitic diatremes, Missouri, USA. Field width 3.5 cm. Note the remarkable similarity of volcanic and impact accretionary lapilli rock texture not allowing to make a prompt distinction.

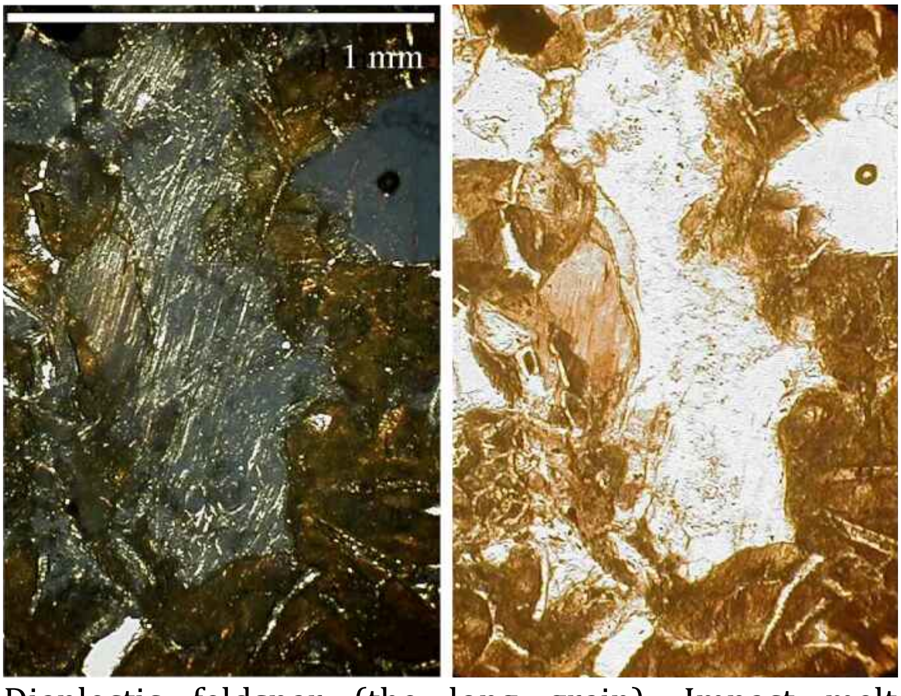
Diaplectic glass



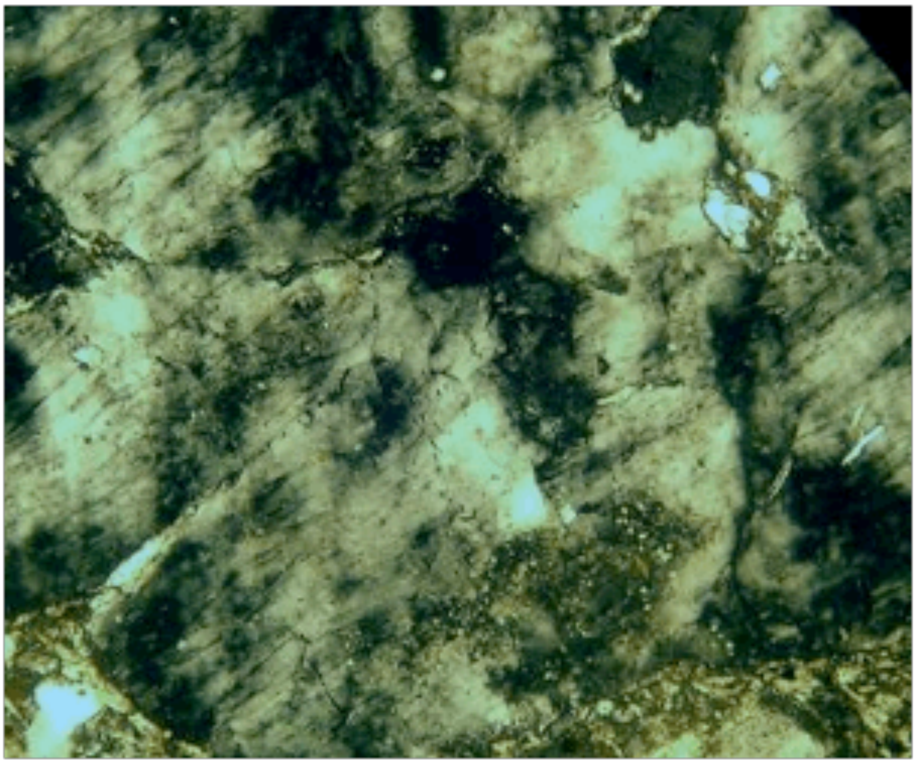
Diaplectic glass in quartz grain, XX, field of view 560 μm. Torrecilla ring.

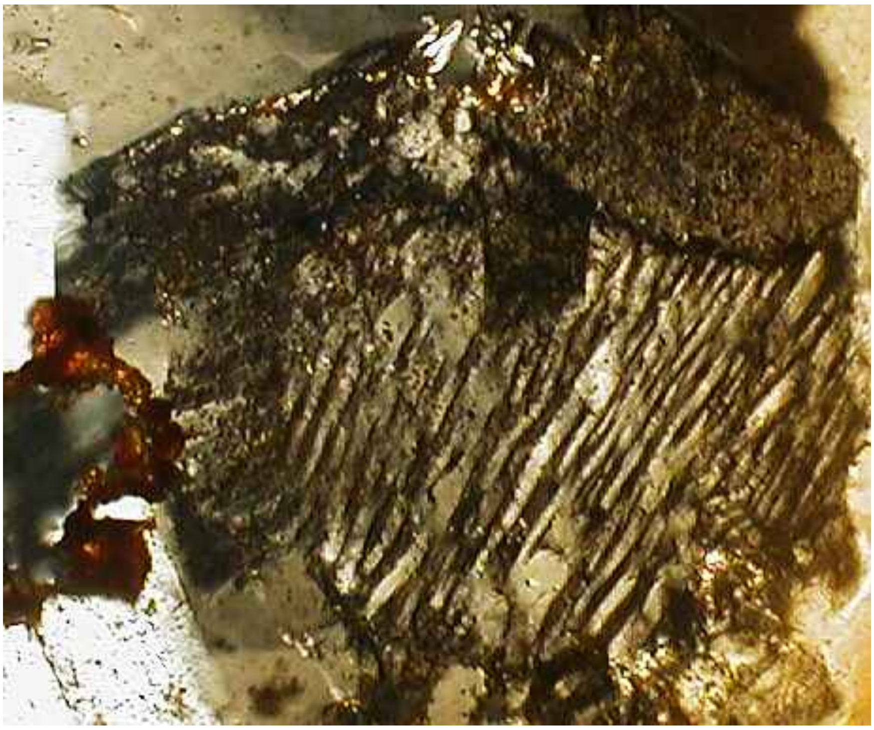


Close-up: Multiple sets of diaplectic glass lamellae.

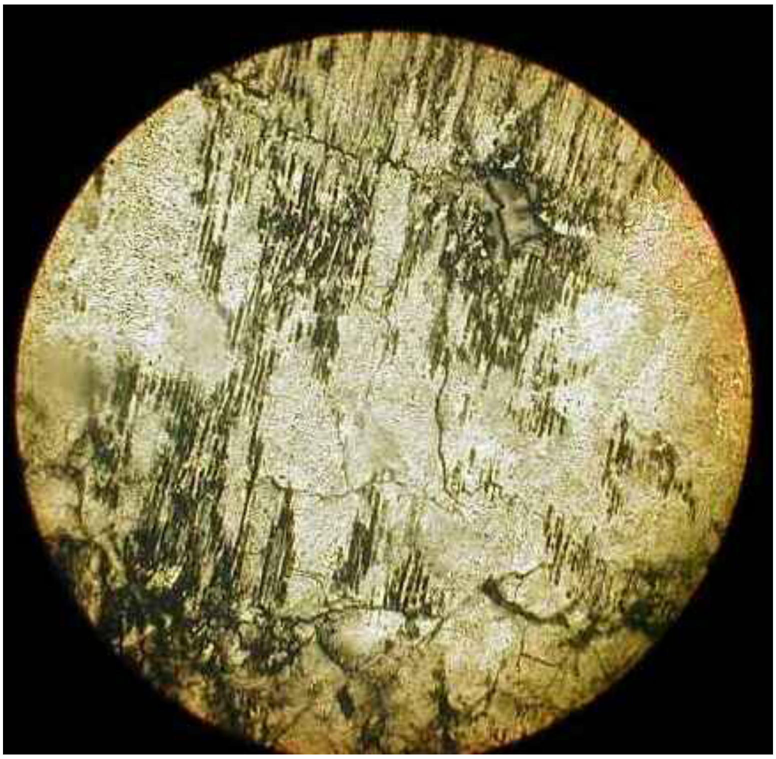


Diaplectic feldspar (the long grain). Impact melt rock, Barrachina megabreccia, XX and PPL. Note the preservation of the grain boundaries and the fractures typically different from melted minerals.


Diaplectic glass and PDF in feldspar. Barrachina megabreccia. XX.

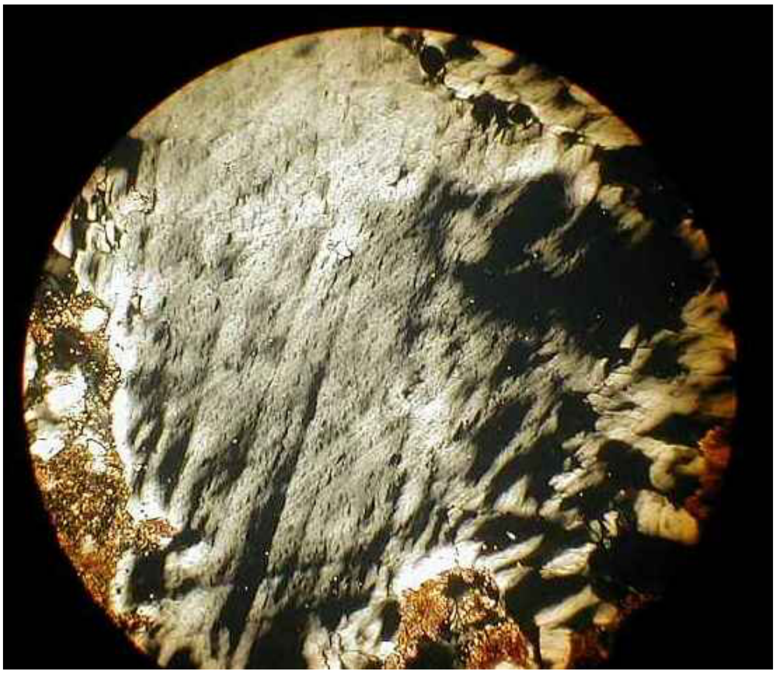


Shocked feldspar with isotropic (diaplectic) twin lamellae and faint PDF, XX. Sandstone, Buntsandstein central uplift in the 10 km-diameter Jiloca-Singra impact crater in the Jiloca "graben".



Shocked feldspar with isotropic (diaplectic) twin lamellae, XX. Cretaceous sandstone; Torrecilla ring.

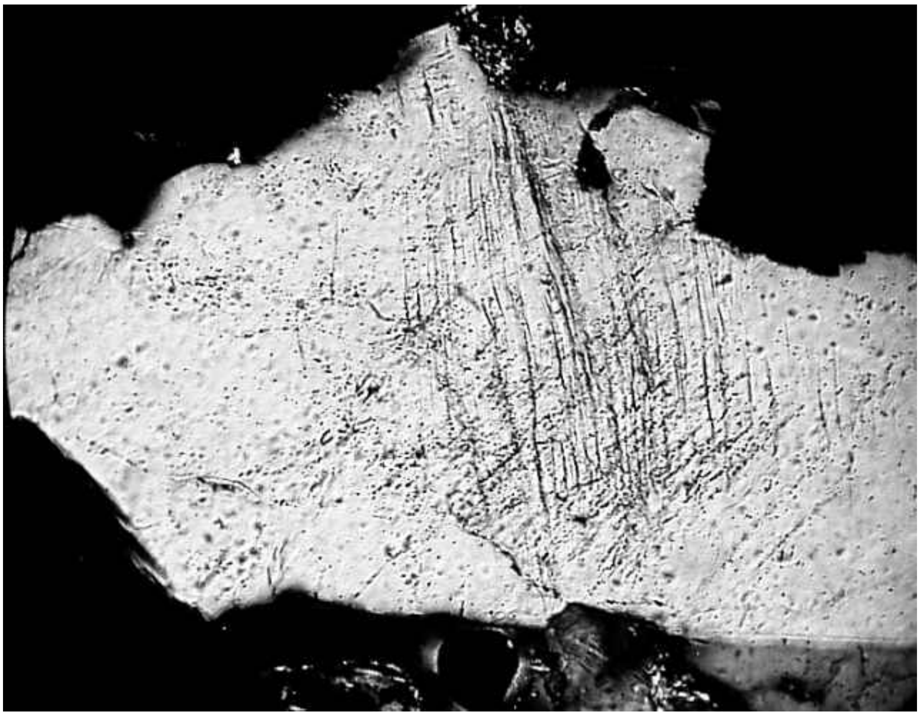
Planar deformation features (PDF)

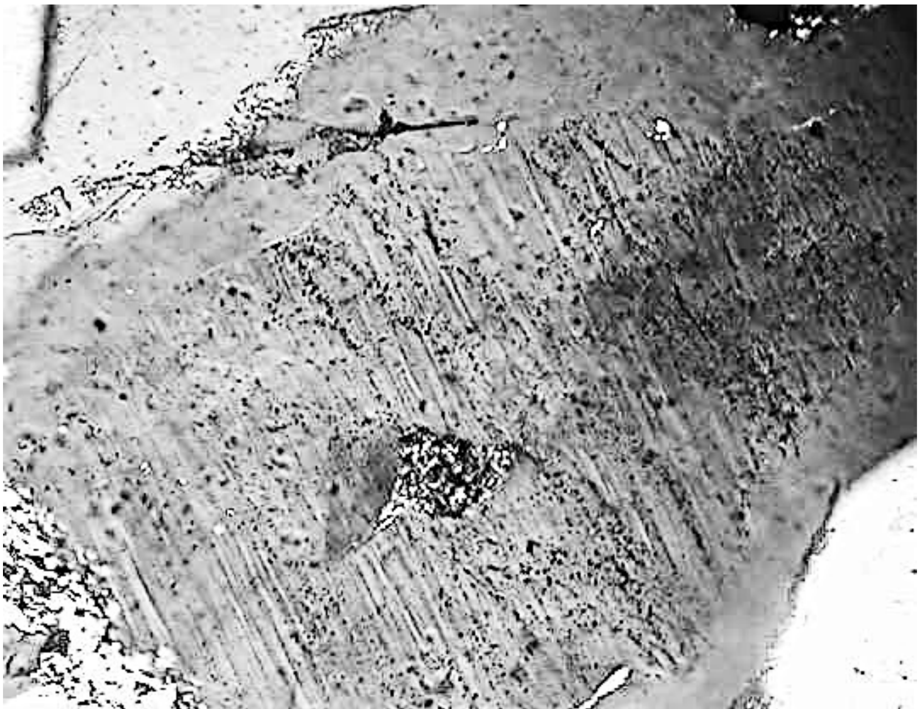


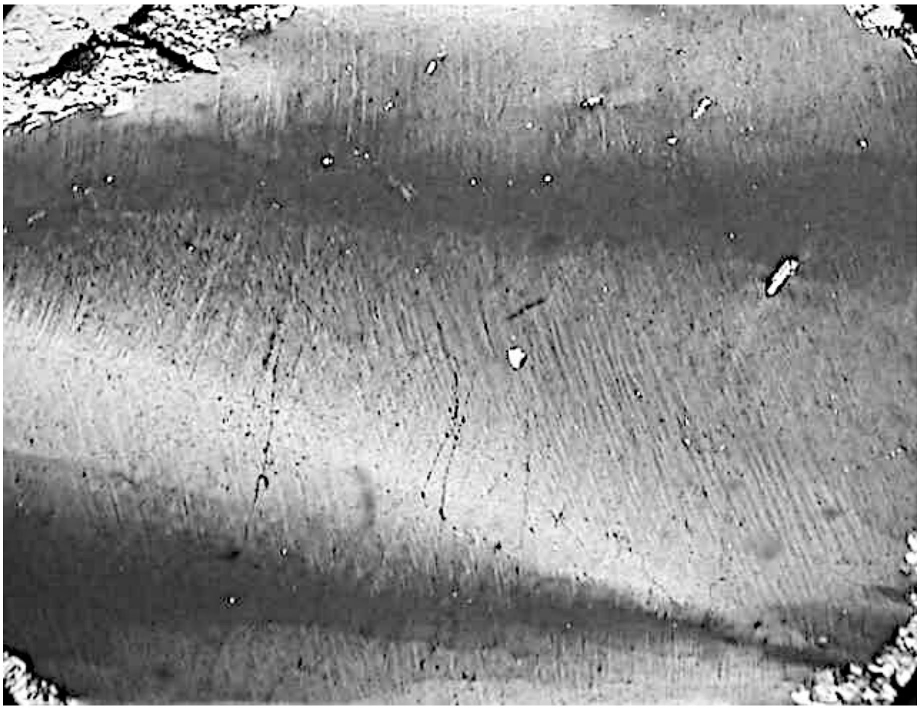
Multiple sets of PDF in quartz merging into diaplectic glass. Torrecilla ring.

Planar deformation features (PDF) in quartz; shocked Cretaceous sandstone; Torrecilla ring near Portalrubio

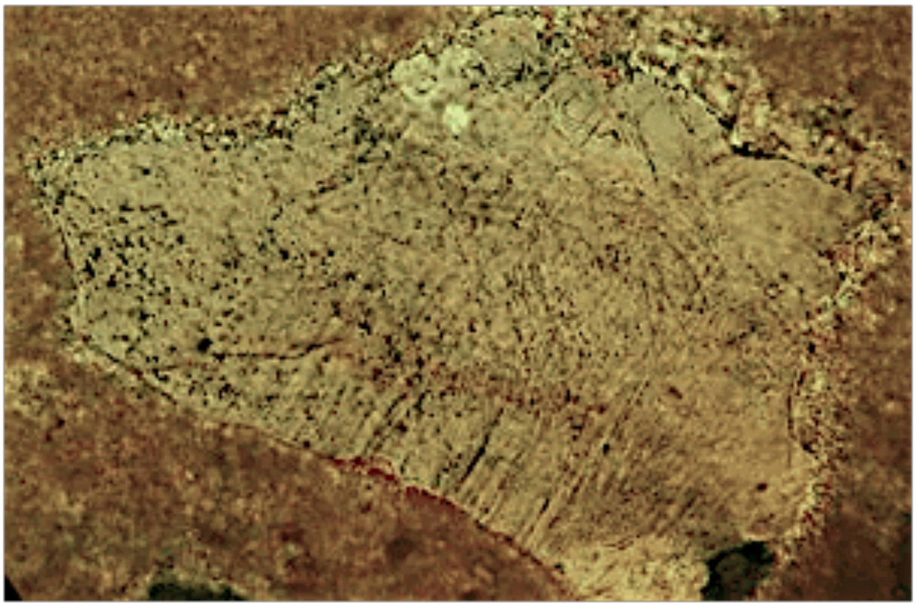
Multiple sets of planar deformation features (PDF) in quartz; shocked sandstone clast, Corbatón.


Multiple sets of planar deformation features (PDF) in quartz; shocked sandstone clast, Corbatón.

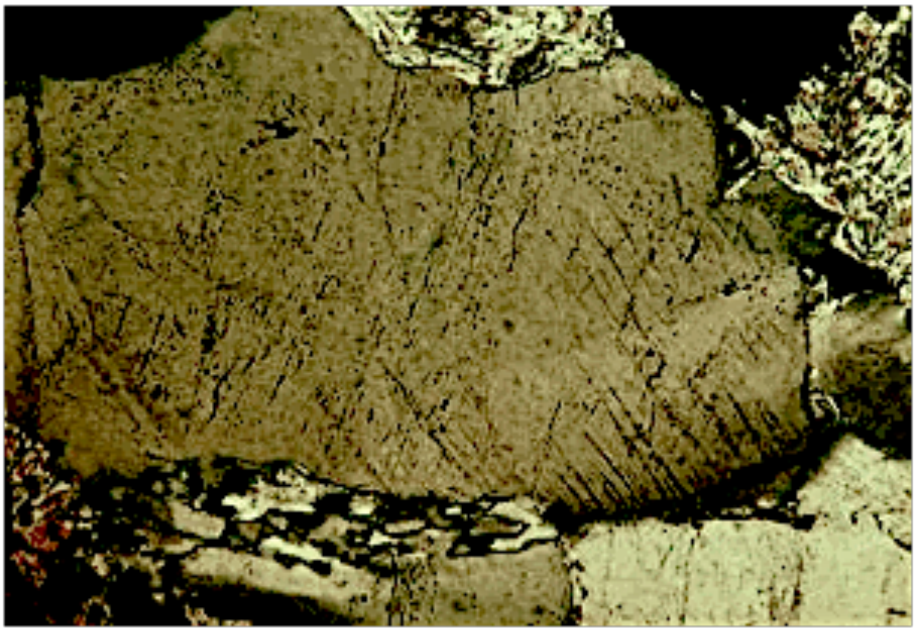

Crossing sets of PDF in quartz. Cretaceous sandstone, Portalrubio.



Kinked deformation lamellae in quartz and associated PDF. Cretaceous sandstone near Portalrubio.



PDFs in quartz; basal suevite breccia near Celadas.



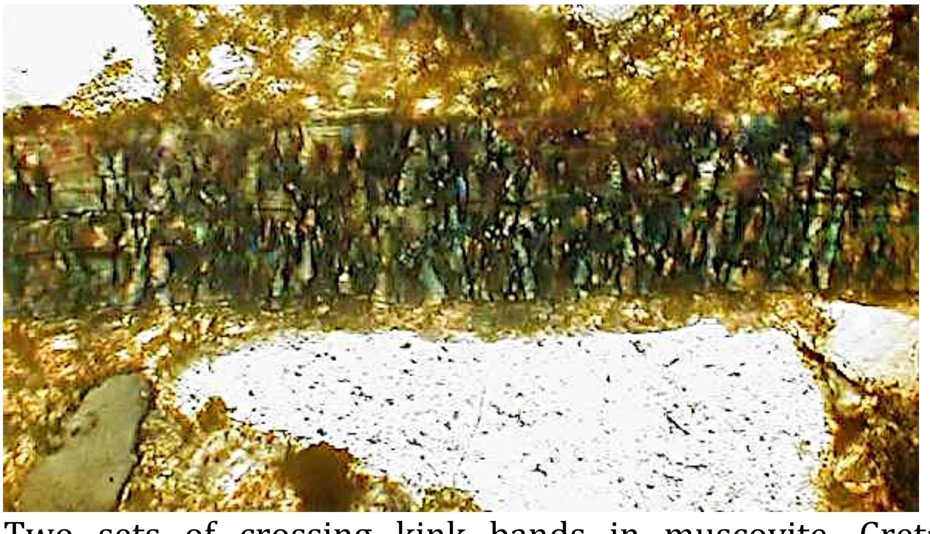
PDFs in quartz; Buntsandstein sandstone, southern basin near Caudé.

PDFs in quartz; basal suevite breccia, northeastern basin rim.

Kink banding - Kink bands

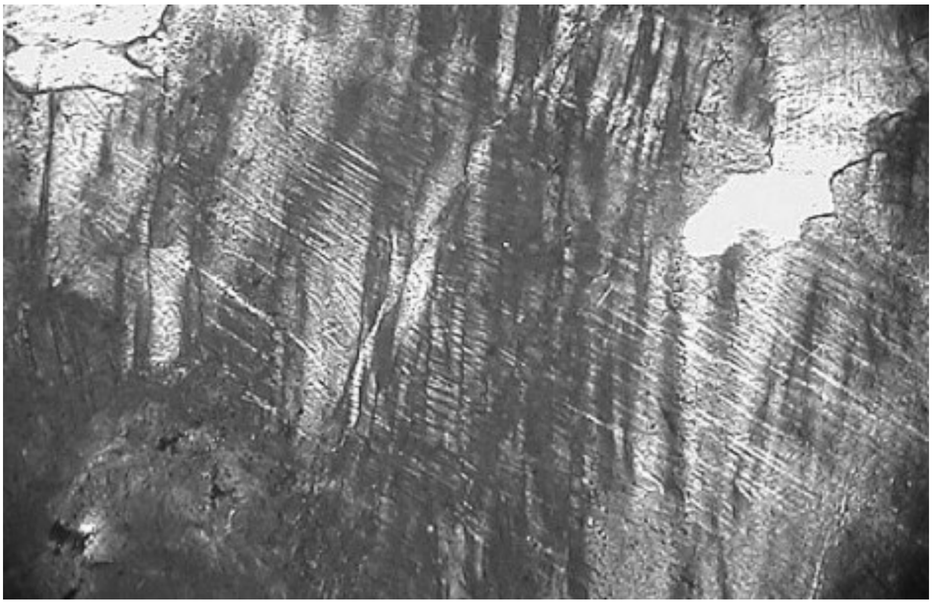
Mica

Multiple sets (four at least) of kink bands in muscovite. Buntsandstein sandstone central uplift, Jiloca-Singra crater in the Jiloca "graben".

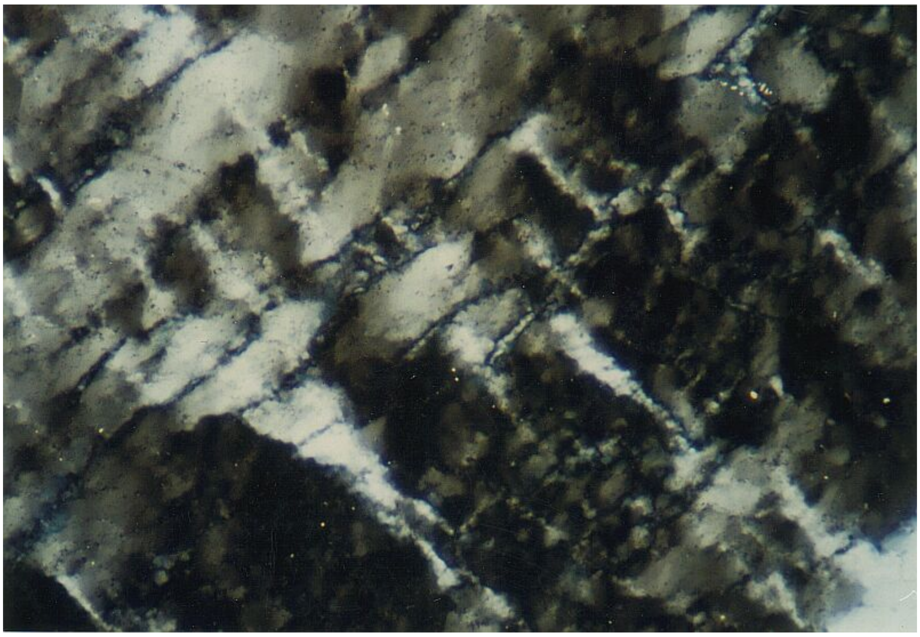


Two sets of crossing kink bands in muscovite. Cretacous sandstone, Torrecilla ring.

Quartz



Deformation lamellae (N - S) and closely spaced kink banding (NW - SE).

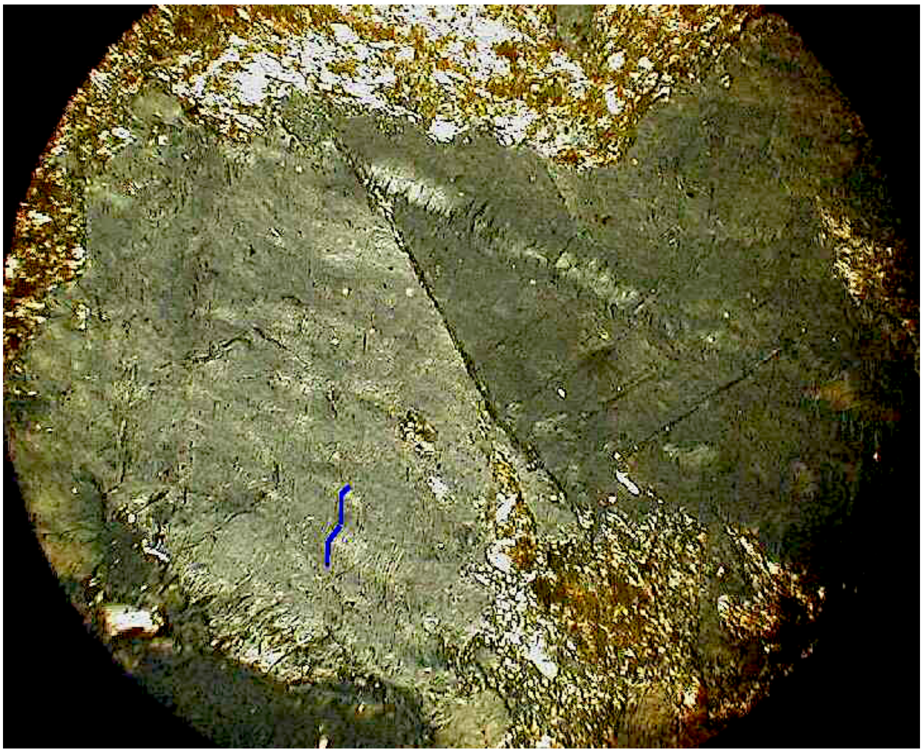


Multiple sets of distinct kink banding in quartz.

Plastically deformed kink bands in quartz and faint PDF.

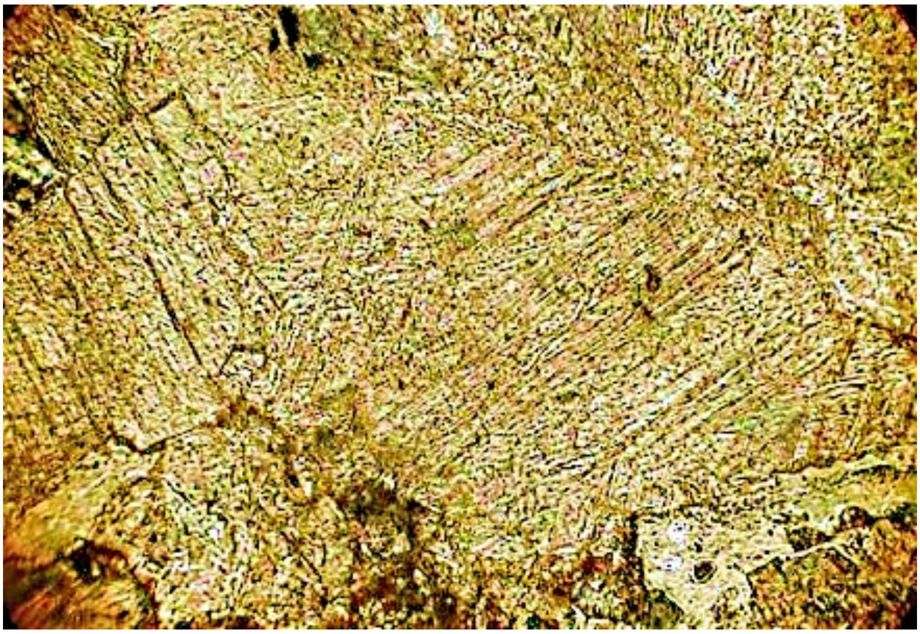
Multiple sets of kink banding in quartz and crossing planar features.

Shock-produced deformation lamellae, planar features and kink banding in quartz - the four images above; photomicrographs, crossed polarizers. Shocked sandstones and quartzites, northwestern basin rim. Width of the fields is between 200 and 500 µm.

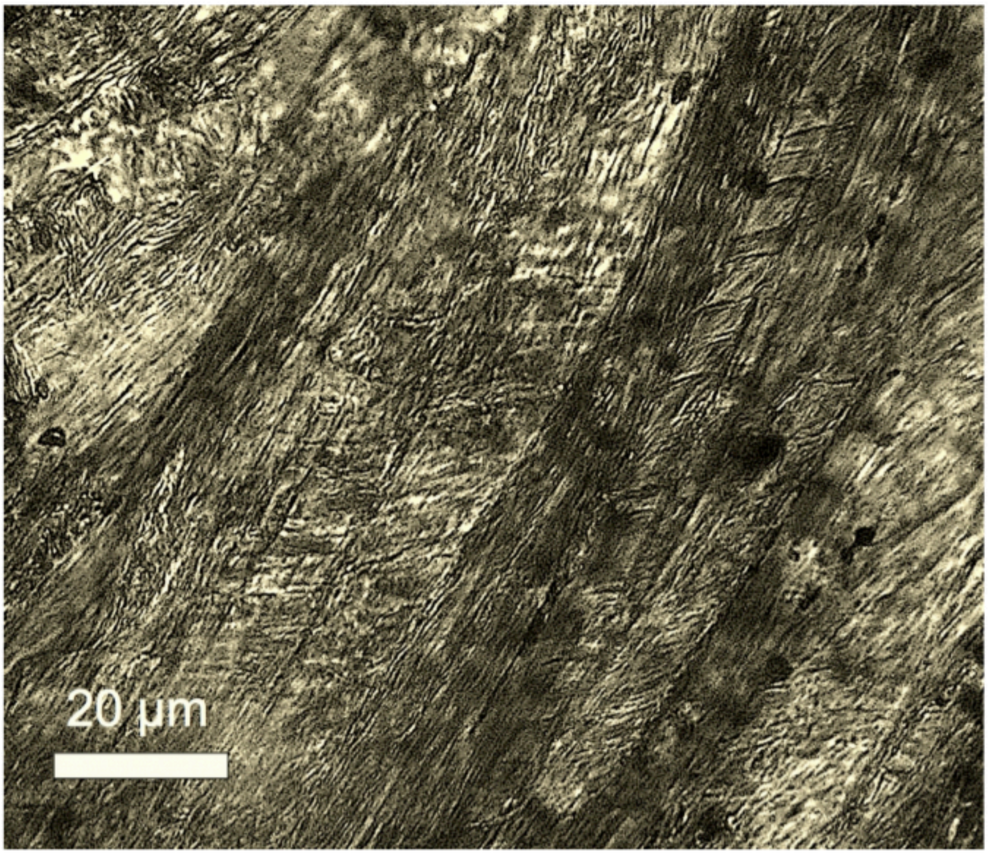


Kink banding and crossing planar features in quartz, Cretaceous sandstone, Torrecilla ring. Field width 350 µm.

Microtwinning calcite

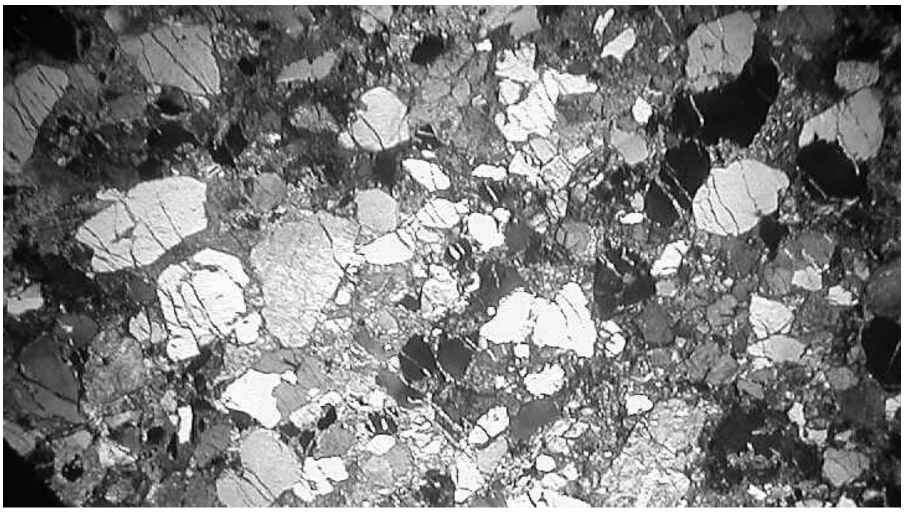


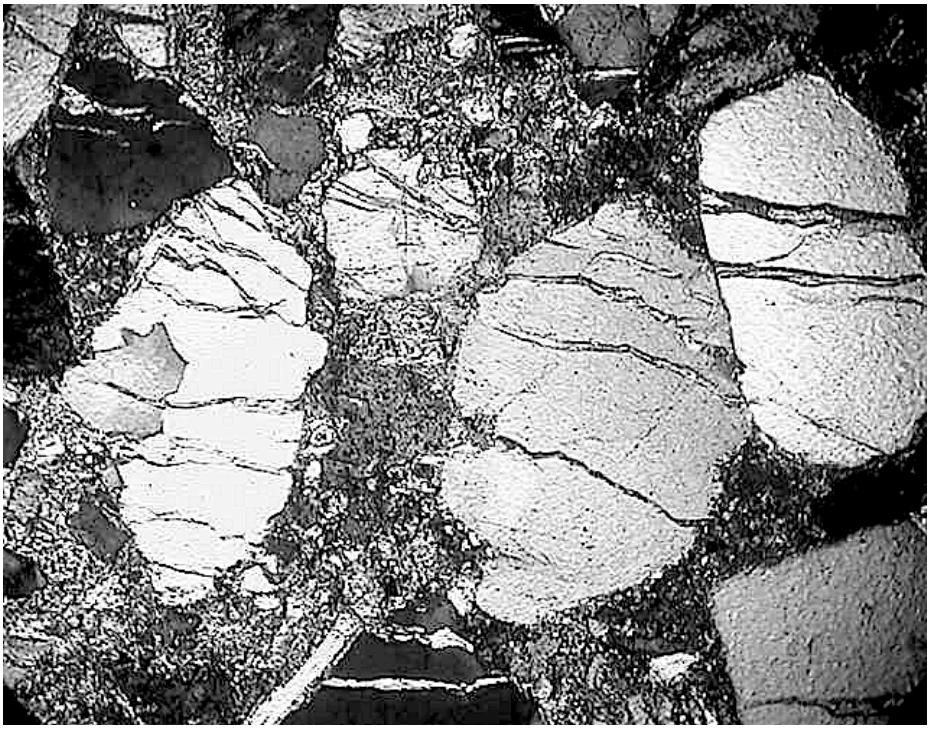
Multiple sets of micro-twins, field width 480 µm. Polymictic breccia Torrecilla ring. Twin size down to 1 µm.



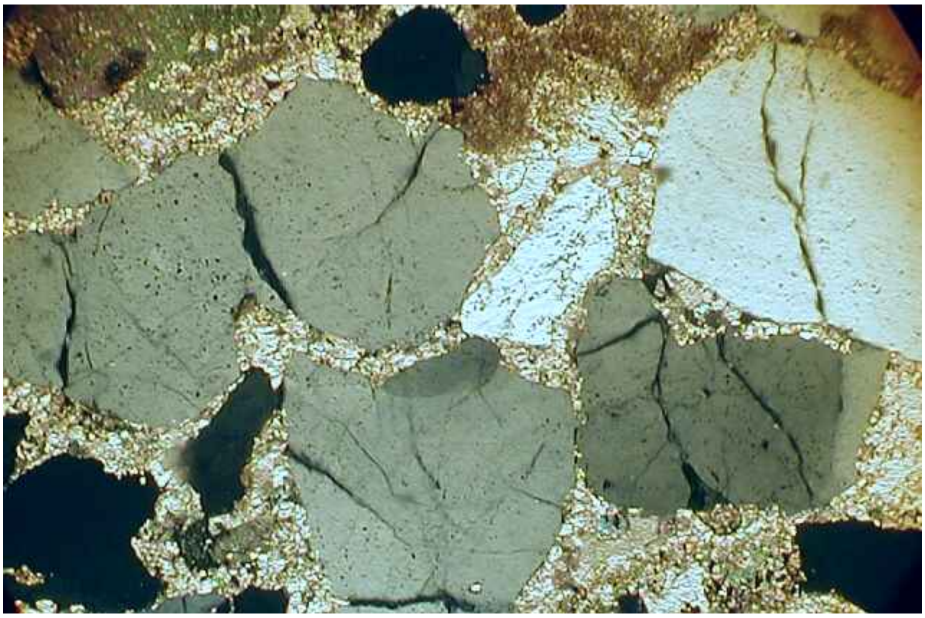
Multiple sets of planar deformation features (micro-twins) in calcite from a polymictic breccia, Torrecilla ring. The twin spacing and width is about 1 µm. Crossed polarizers.

Shock spallation

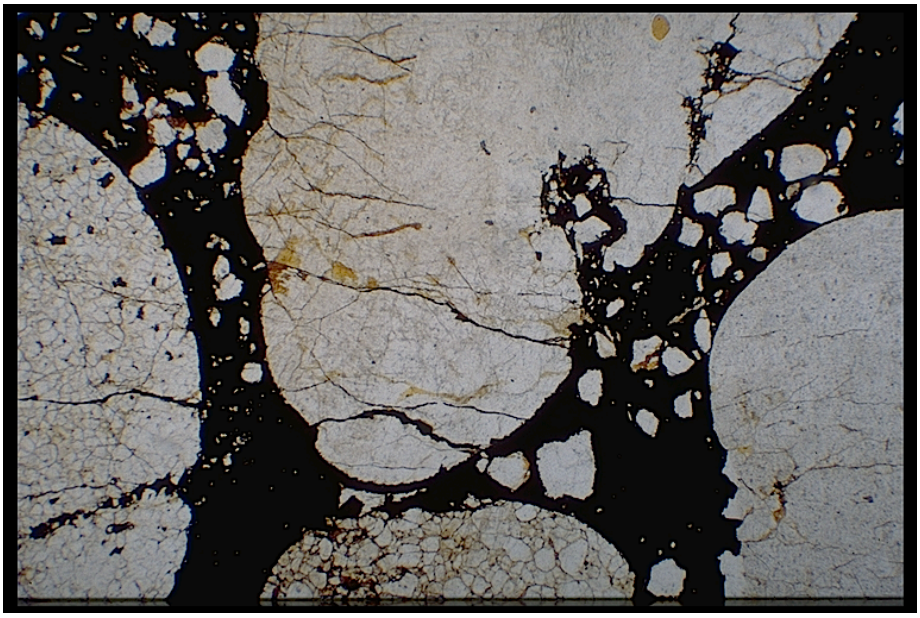

Shocked sandstone with subparallel open spallation fractures in quartz grains. The shock front moved from WSW to ENE, or vice versa. Photomicrograph, crossed polarizers, field width ca. 2.5 mm. Buntsandstein central uplift, Jiloca-Singra crater in the Jiloca "graben".



More shocked quartz grains in a sandstone from the central uplift. Sample with distinct subparallel open spallation fractures. Field width ca. 800 µm.



Open shock spallation fractures in quartz, XX, Cretaceous sandstone Portalrubio.



Spallation: A spall is completely (2-D) detached from a quarzite grain in a shocked Buntsandstein conglomerate, and more open tensile spallation fractures are cutting through the clasts. The image shows pure tension without contact between the neighboring grains (in 2-D). The matrix is opaque from iron-hydroxide. Field width 9 mm. Central-uplift chain near Caudé.