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Surface analyses of archaeological objects. Some new perspectives with Laser Scanning Microscopy

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Abstract: The development of computer-aided microscopy opens new opportunities for the documentation of anthropogenious surface modification of archaeological finds. Laser Scanning Microscopes contribute significantly to advances in quantifying the surface topography of objects, as is shown here on two kinds of human modified finds: The first example deals with cutmarks on animal bones, shown here on some very remarkable objects from the Middle Pleistocene site of Bilzingsleben. The main focus is on bones with regular engravings associated with intentional activity of early humans. Characterising the cuts this way reveals new indications of the amazing regularity, probably on every bone produced by the same cutting edge of a tool.
Surface modifications of cutting edges on flint tools were also investigated, in order to differentiate possible use-wear from sedimentological alteration. Measurment of roughness becomes possible within well-defined technical parameters. Given the technical potential of LSM there very promising data-based systems for quantifying modifications on both lithic artefacts and bones can be developed.

Human manipulations and cut marks on animal bones are principally well known from the last decade of research. However, documentation of prehistorical marks is presented mostly by a written description with only a few reference pictures from light- or electron microscopy (J. Cook 1986; H. T. Bunn & E. M. Kroll 1986; R. Potts 1988; P. Shipman 1993). Laser Scanning Microscopy (LSM) contributes significantly to advances in quantifying the surface topography of cut marks and other modifications. With LSM investigations it is possible to quantify profile information, such as the wall-angle of the mark, its width and depth. Quantified information will bring comparable evidence of anthropogenic cuts and opens possibilities to distinguish them from postdepositional scratches. The used confocal Laser Scanning Microscope works with a Helium-Neon-Laser and has a resolution up to 500 nm. For investigating the surface topography and reference profiles it is useful to choose a resolution of about 3 µm.

Deliberate Marks on Bones from Bilzingsleben

During 30 years of field work, which has yielded tons of faunal remains, the Bilzingsleben team has uncovered many examples of functional cut marks and bones which served as working surfaces. With its excellent preservation of faunal remains, diverse cranium fragments from *Homo erectus bilzingslebenensis* (E. Vlček 1978) and thousands of flint artefacts, Bilzingsleben is one of the best preserved Middle Pleistocene sites (D. Mania & U.

Mania 2000). Although 40-60% of the bones and flint tools were found in situ (D. Mania & U. Mania 2000), most of the surface modifications are hard to define as human manipulated or not. Only quantification of data seems to be an approppreate way of finding criteria for identifying anthropogenic signatures. New opportunities given by Laser Scanning microscopy can provide for useful comparisions with experimental studies at one and other archaeological sites on the other hand.

Some examples show new analyses of the most remarcable objects from Bilzingsleben: In 1988 were published four very remarcable bone objects, showing cut marks on the surfaces in exciting arrangements (D. Mania & U. Mania 1988). While the first discussion (*Rock Art Research Vol.5/2 and 6/2*) was misleaded only to questions of art or intended meanings, in the late 90´s was the time to verify the physics of the cuts.

One of the artefacts, a thin bone fragment, was found laying in close contact with the upper surface of a travertine block. So the cuts are exceptional well-preserved. Eight lines were engraved at regular intervals. The profiles, show very clear evidence for cuts, done with probably the same edge of one lithic tool. Characteristics for cut marks are the V-shaped profiles with a uniform wall-angle, regularity along the wall in depth and along the stroke. The force of cutting was well proportioned, so all cuts are about 60-90µm deep *(fig. 1).*

The flat-convex outer surface of the medial fragment of a mammal rib shows four parallel, oblique lines, arranged at different distances. Each marking consists of three single lines of an overlapping order at the ends. All these lines are morphologically uniform, and we infer that one single flint implement was used in their production *(fig. 2).*

Third of these objects and maybe the best known is a femur spall of *Elephas antiquus*. Its length is about 40cm, the thickness about 6.5cm. A group of radial lines begins with 7 longitudinal, slightly divergent cuts. The flat surface shows a sequence of 14 straigtht lines in very regular arrangement. Unfortunatily the object is too thick for the microscopic table. So it was necessary to work with replica of the cuts to produce one reference profile of each mark *(fig. 3).* Although the surface of the bone was relatively rough, regularities can be seen in the cross-sections. All profiles display trapezoidally cutting lines, probably produced by blunter edge of a tool. The range of depth is regular and about 50 +/- 20 µm.

On the other hand, it is necessary to differentiate these anthropogenious cuts from postdepositional scratches, caused by fluvial redeposition. We began to work both with comparable material from other sites, experimental studies and more Bilzingsleben objects. On a bone fragment (pelvis of *Stephanorhinus kirchbergensis/ hemitoechus*) from the fluvial redeposited shore zone more than 30 scratches were identified. They are all caused by the transport in the sandy sediments. Typical cross-sections are flat, the walls are rounded and the strokes are inhomogenious *(fig. 4).*

Though not all differences are that clear there is no indication, that the characteristics of functional cut marks and the regular engraved objects would overlap (L. Steguweit 1999). These data strengthen the thesis, that Bilzingsleben shows clear evidence for nonutilitarian activity in the context of early human culture.

LSM Investigations on Flint Surfaces

Considering the difficulties in defining polish formation in phenomenological descriptions, some workers described methodological problems in differentiating possible use-wear from sedimentological alterations (J. Kamminska et al. 1993; I. Levi-Sala 1996) or additive particles (J. Kamminska & K. Szymczak 1999). Postdepositional surface modifications can appear as a formation of opal, which can completely overlie anthropogenic abrasion (L. Steguweit 2001; 2003, 85-91).

The research of Yamada (1993) showing the progressive abrasion process during well-defined working strokes, was helpful in defining conditions, under which experimental "*use wear polishes*" develop. Within LSM, measuring of surface roughness becomes possible in well-defined technical parameters. The parameter (R_a) is the mean surface roughness. That way the abrasion process of a rounded edge, caused by intensive smoothing of a jew-wooden spear (30min.), can be shown with a reduction of the grain surfaces from about 12 µm to about 3 µm ($2R_a$ for the description of the full grain depth) (*fig. 5*).

Because of different effects of postdepositional surface modifications there is little evidence for direct analogies between experimental polish and similar phenomena on prehistorical artefacts (I. Levi-Sala 1996). New mineralogical investigations show a general mechanism of silica transport and accumulation by $Si(OH)_4$ diffusion in pore solutions also at low temperatures (M. Landmesser 1995). Old artifacts made of Baltic flint often display smoothed, polish-like surfaces, which are different from fresh flakes. New investigations with both SEM and LSM roughness parameters offer an explanation, in which the secondary formation of opal smooths the grain structure of the flint surface (*fig. 6*).

Secondary formation of opal on the surface of coarse grained Baltic flint can smooth the surface up to $R_a < 1$ µm, completely overlying possible anthropogenic abrasion. Under special sedimentological conditions a serious limitation for light microscopical investigations is given. This contribution offers critical aspects to *High Power* analysis of polish phenomena. The technical potential of LSM requires more prehistoric samples which will provide more conclusive evidence for postdepositional surface modifications on different raw materials.

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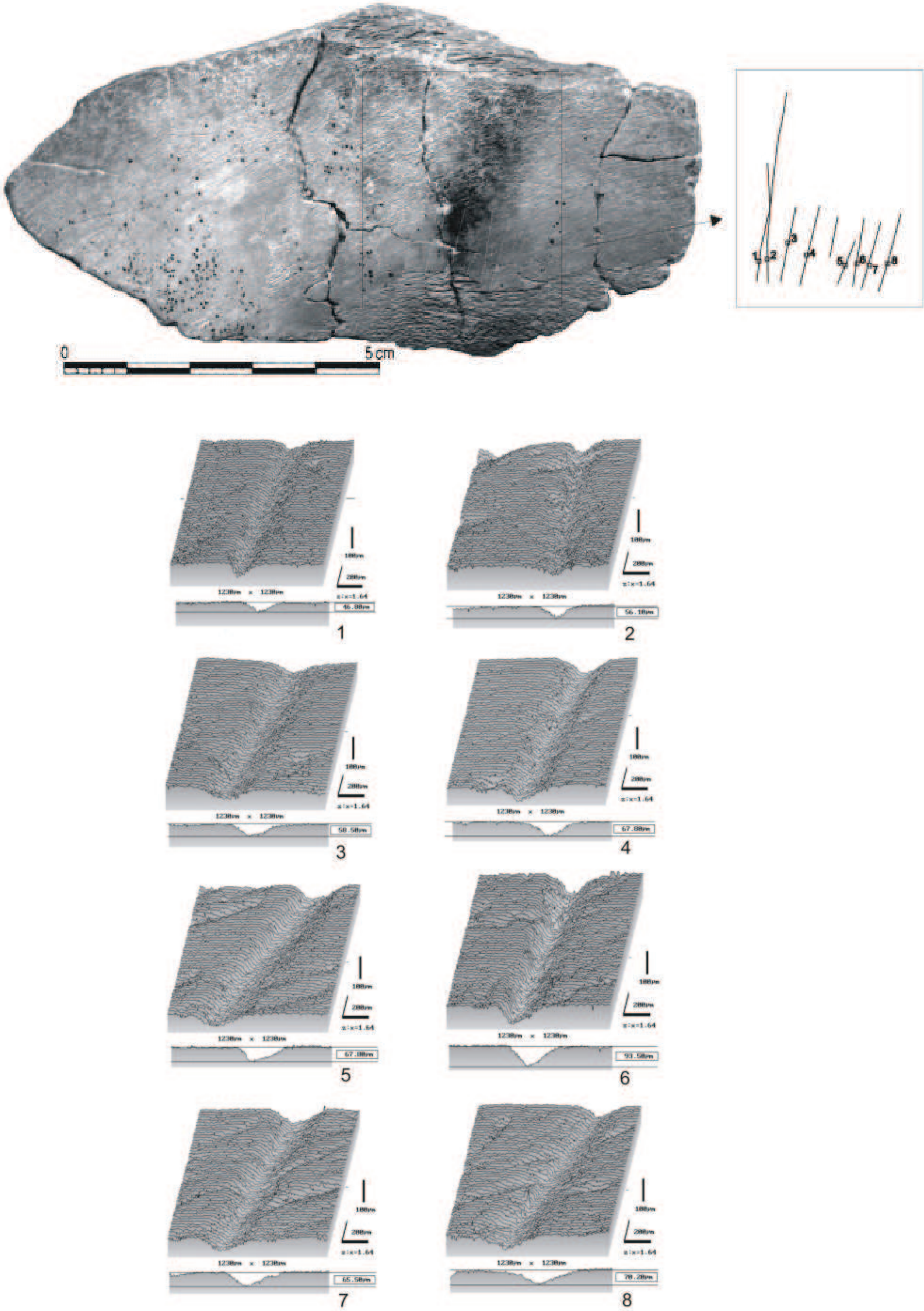

Fig. 1 – Bilzingsleben, Bone fragment (No. 182, 32) with cut marks

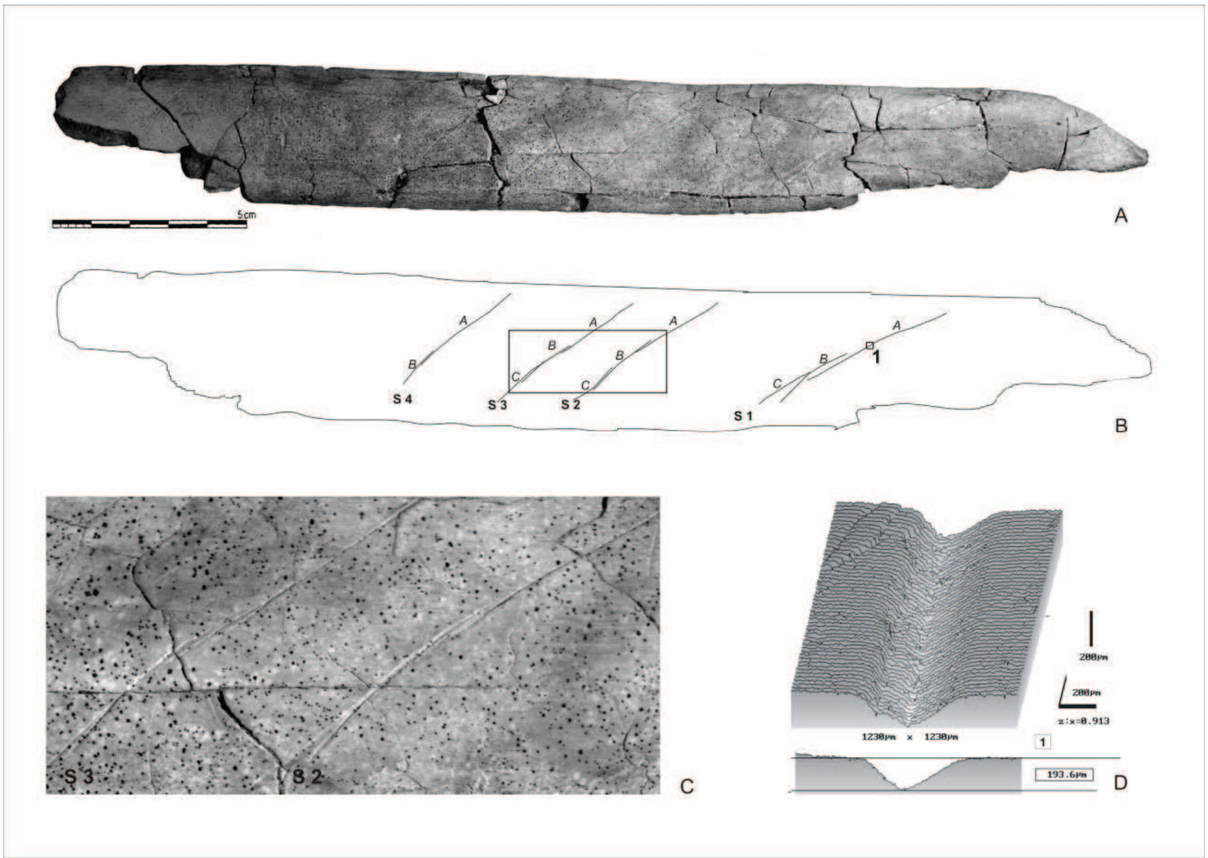

Fig. 2 – Bilzingsleben, Rib fragment (No. 219, 34) with cut marks

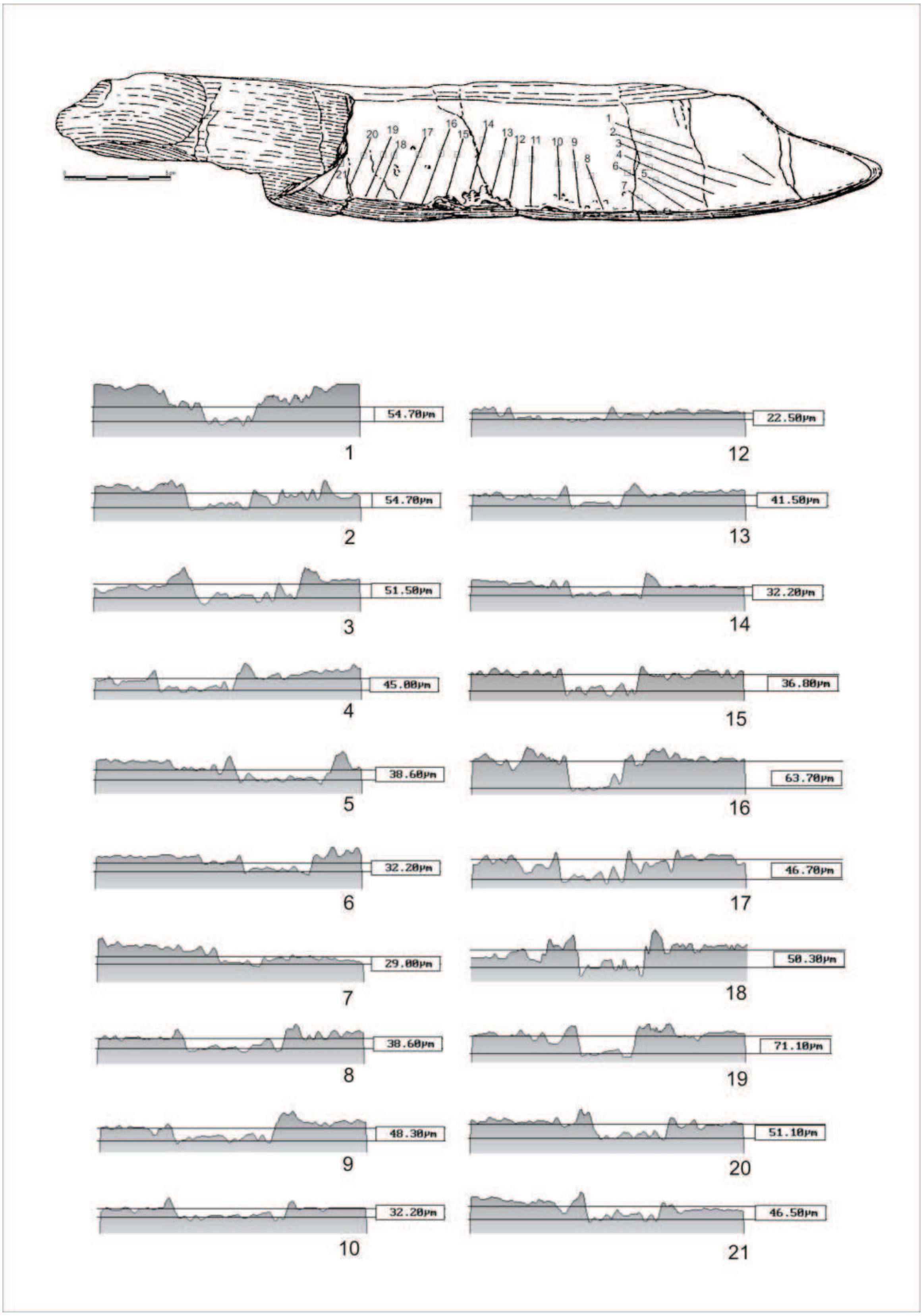

Fig. 3 – Bilzingsleben, Femur spall of Elephas antiquus (No. 208, 33) with cut marks

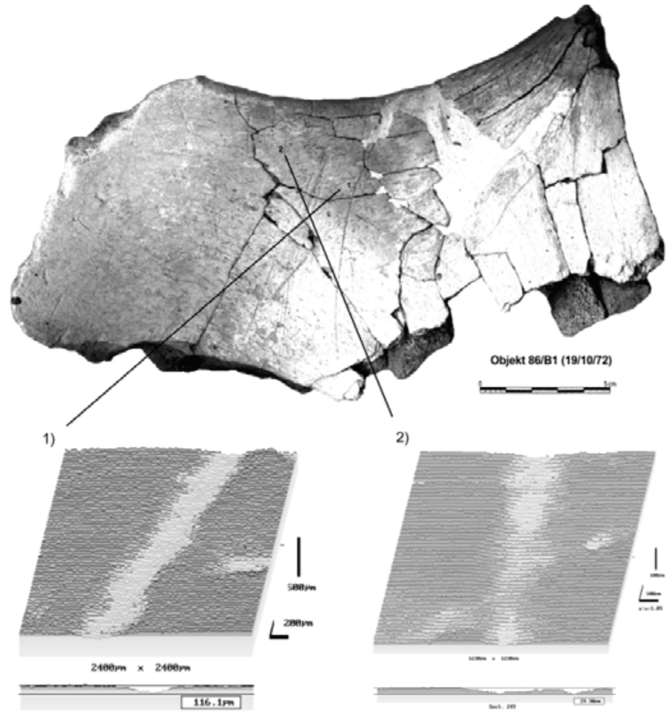

Fig. 4 – Bilzingsleben, Pelvis fragment of Stephanorhinus (No. 86/B1) with sediment scratches

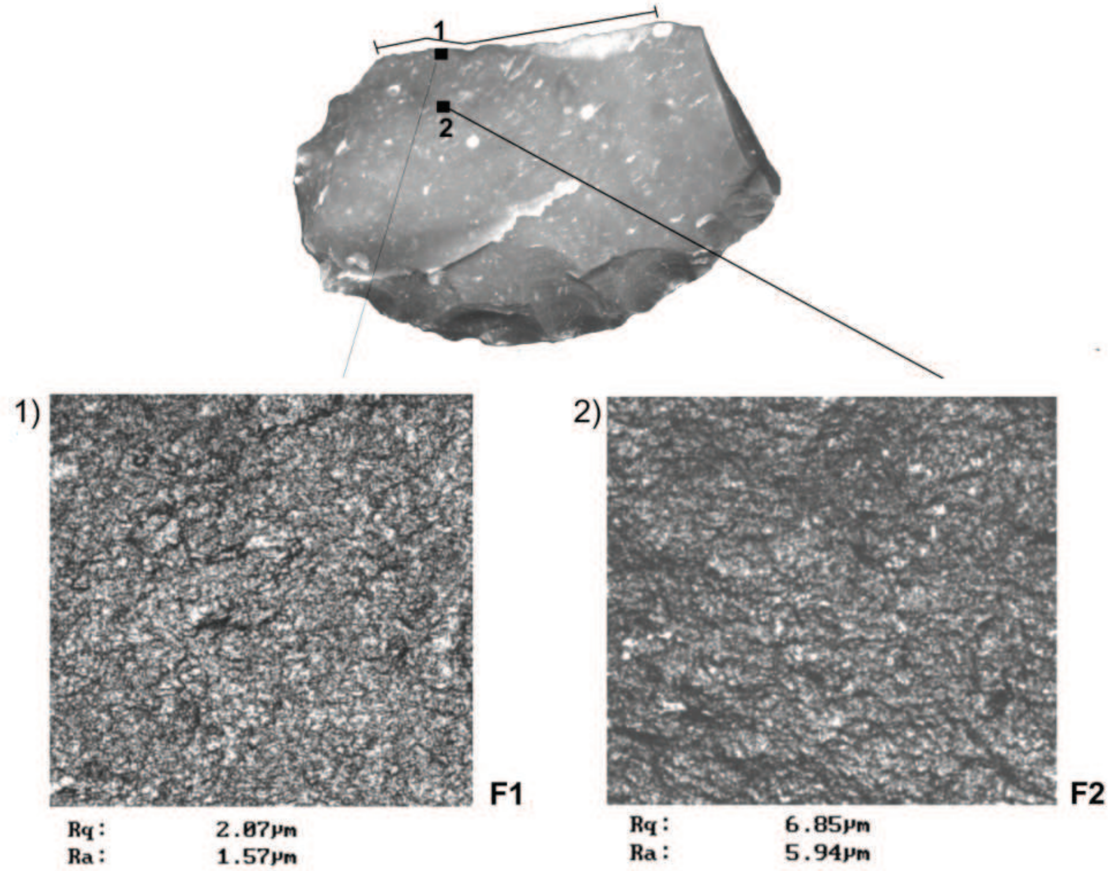

Fig. 5 – Experimaental study of edge rounding with LSM roughness parameters

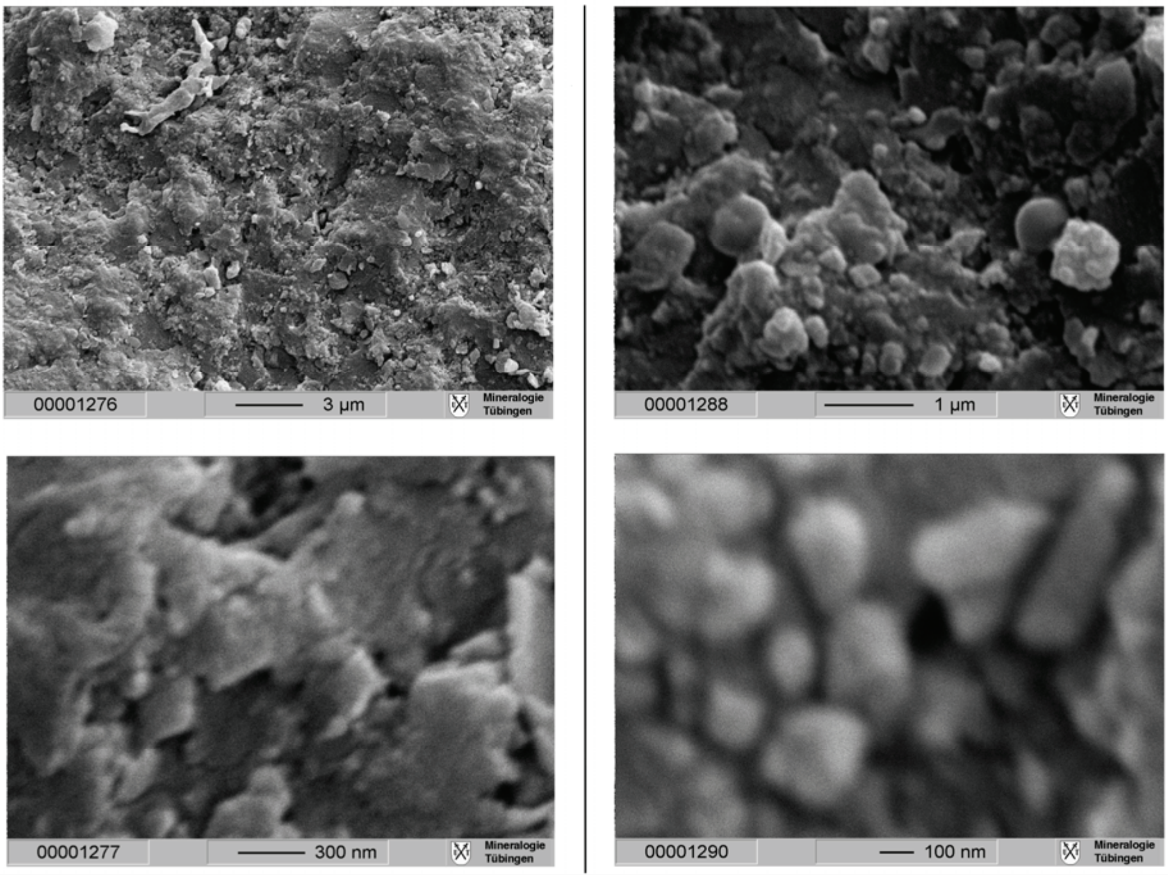

Fig. 6 – SEM photos of a Baltic flint, fresh flake surface (left),
the same raw material with secondary surface opalisation on the outer surface ***(right)***