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Combined Geological and Paleomagnetic Analyses of the Back Plane of the Eastern Buddha Niche, 2007

Geological criteria and paleomagnetic measurements

As mentioned before, the geological approach to discriminate the required reference pattern is based on a detailed survey of the varying sedimentological and structural features of the respective layers. A two profile design was chosen covering the right and left hand sides of the eastern back wall to account for the suspected lateral variability of the sediment layers (fig. 2).

Both profiles start immediately above the ceiling of the caves, i.e. at 2538.469 m.a.s.l. (profile 1, left or western side) and 2538.445 m.a.s.l. respectively. The respective starting points in meters above sea level (m.a.s.l.) were levelled using a laser aided air level using the reference point of 2535 m.a.s.l. near the floor of the niche also used in the recent ICOMOS related activities including the 3D laser scan of the eastern niche. Between the starting point of a profile and its respective end point a tape measure was than fixed to the back plane of the niche.

For the rock magnetic measurements we used the newly acquired (University of Cologne) handheld magnetic susceptibility meter SM-30 (ZH-Instruments, CZ) which has a sensitivity of 1 x 10^{-7} SI units and hence can measure rocks with very low susceptibilities or even diamagnetic substances. The sensitivity of the instrument is about one order of magnitude higher compared to the instrument (KT-5) we had been using during our previous missions (precursor instrument by the same manufacturer). Several tests on-site indicate that both instruments yield comparable results, albeit with a better resolution of weakly magnetized layers by the new instrument (figs. 2–4). Measurements were taken at about every 5 cm throughout both profiles, largely determined by the 50 mm pick up coil of the SM-30 (KT-5 was 6 cm).

Situation on site, Eastern Buddha

Both the geological as well as the magnetic analyses require direct contact with the material to be investigated. Hence, unrestricted access to the back plane of the niches and the respective fragments is the essential prerequisite for the success of the suggested pattern matching approach.

Due to the unknown material properties of the steel pipes used to construct the scaffold several tests needed to be performed as to understand any potential effects on the magnetic measurements. Critically, the metal scaffold would potentially influence the measurements of magnetic susceptibility both of the back plane of the niche as well as from the few larger fragments left within the niche which are closely encased by the foundation pillars of the scaffold (fig. 1).

Back plane (reference profiles), Eastern Buddha niche

A reference section of the back plane of the Eastern Buddha niche was successfully completed from 2538.4 m.a.s.l. to 2552 m.a.s.l. (figs. 2, 3 and 4). Both the lateral and vertical variability of rock layers is much higher than had previously been suspected and, hence, yielded very promising results for the pattern matching approach. A classification in terms of 15 lithological units is suggested which accommodate overall depositional facies of the sediment (fig. 3). Apart from prominent colour changes, component composition, size and shape variation of the prevailing silty, sandy and conglomeratic through breccious units variations in the amount and composition of the sediment matrix are dominant features of the geological succession. The amount of matrix ranges from almost 80 vol% (matrix supported fabrics) through absent in the clast supported fabrics. The amount and composition of matrix (natural cementation)

Fig. 1. Extensions made to the original scaffold consist of two grounded towers to a maximum height of about 20 meters above ground. Shown here is balcony type in the upper part. Any extensions to the scaffold reaching up higher were avoided in order to not interfere with the most unstable parts of the rock surface within and directly below the shoulder area.

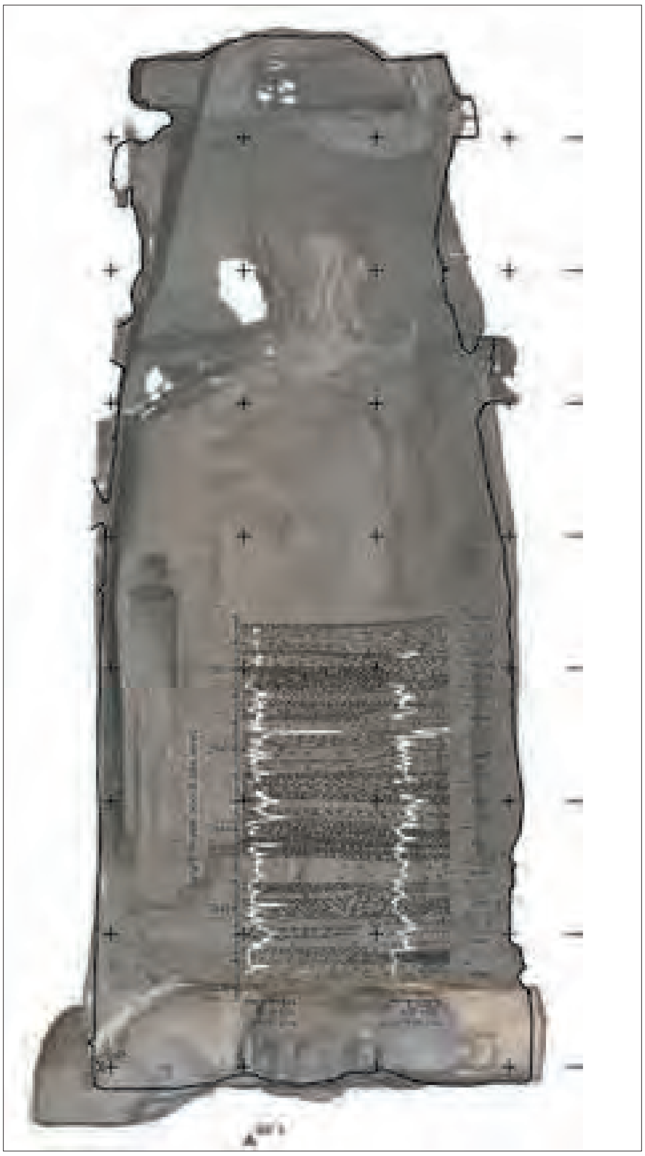

Fig. 2. Position and lengths of the two main profiles (reference sections) within the eastern Buddha niche. Profiles start at 2538.4 m.a.s.l. right above the chambers. Background 3D scan courtesy of RWTH Aachen group. Lithology as a result of the November 2007 geological survey is also shown as a detail in figure 4.

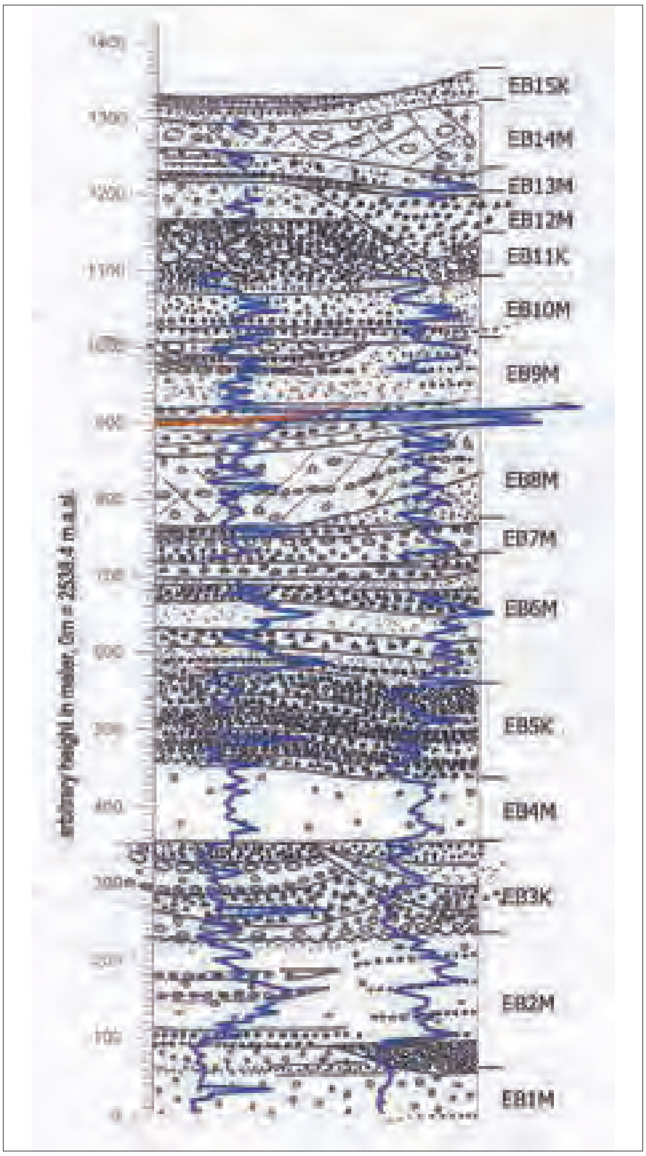

Fig. 3. Lithological details of the eastern back wall between 2538.4 and 2552 m.a.s.l. Scale on the left side is in meters arbitrary height. Colour coding approximates actual colour variations of the rock, signatures approximate lithological variations from silty through conglomeratic material. Note high lateral variability, for example in unit EB3K (channel fills), where EB3K denotes Eastern Buddha unit 3 clast supported fabric (M units indicate matrix supported fabrics). Blue curves = susceptibility κ. For details of respective lithological units see the next page.

will directly affect the stability of the respective rock units and can be used as a rough (relative) estimate of the uniaxial shear strength (see report Fecker 2006). As a rule-of-thumb clast supported fabrics will have the least stabilities. It is clear from the detailed geological survey that the stability of the rock face will vary on a small scale (cm) both laterally and vertically (and 'into' the wall when viewed two-dimensionally).

Generally, while the assumption of overall near horizontally bedded layers is confirmed, the internal lateral variation within the lithological units reflect a high energetic depositional environment with usually high to very high accumulation rates, especially for those units composed of unsorted, breccious material with clast sizes up to 25 cm across. As I stated in previous reports (see p. 89 ff.) all the layers appear to be erosion material from the surrounding elevated parts of the relief (i.e., the uprising Hindukush mountain chains in the Tertiary largely in the course of the ongoing Indian – Asian collision and the Himalayan orogeny) and as such were deposited in the developing intramountain Bamiyan basin as high energetic debris flows, or, for example material charged streams (channel fills reflecting a typically high spatial and temporal variability, hence, alternatively deposition and erosion) originating in the higher parts of the relief.

Magnetic susceptibilities (with κ around 50 x 10^{-5} SI units) are on the same order as was noted for the Western Buddha sedimentary succession and display an equally distinct variation with the lithology (figs. 3 and 4).

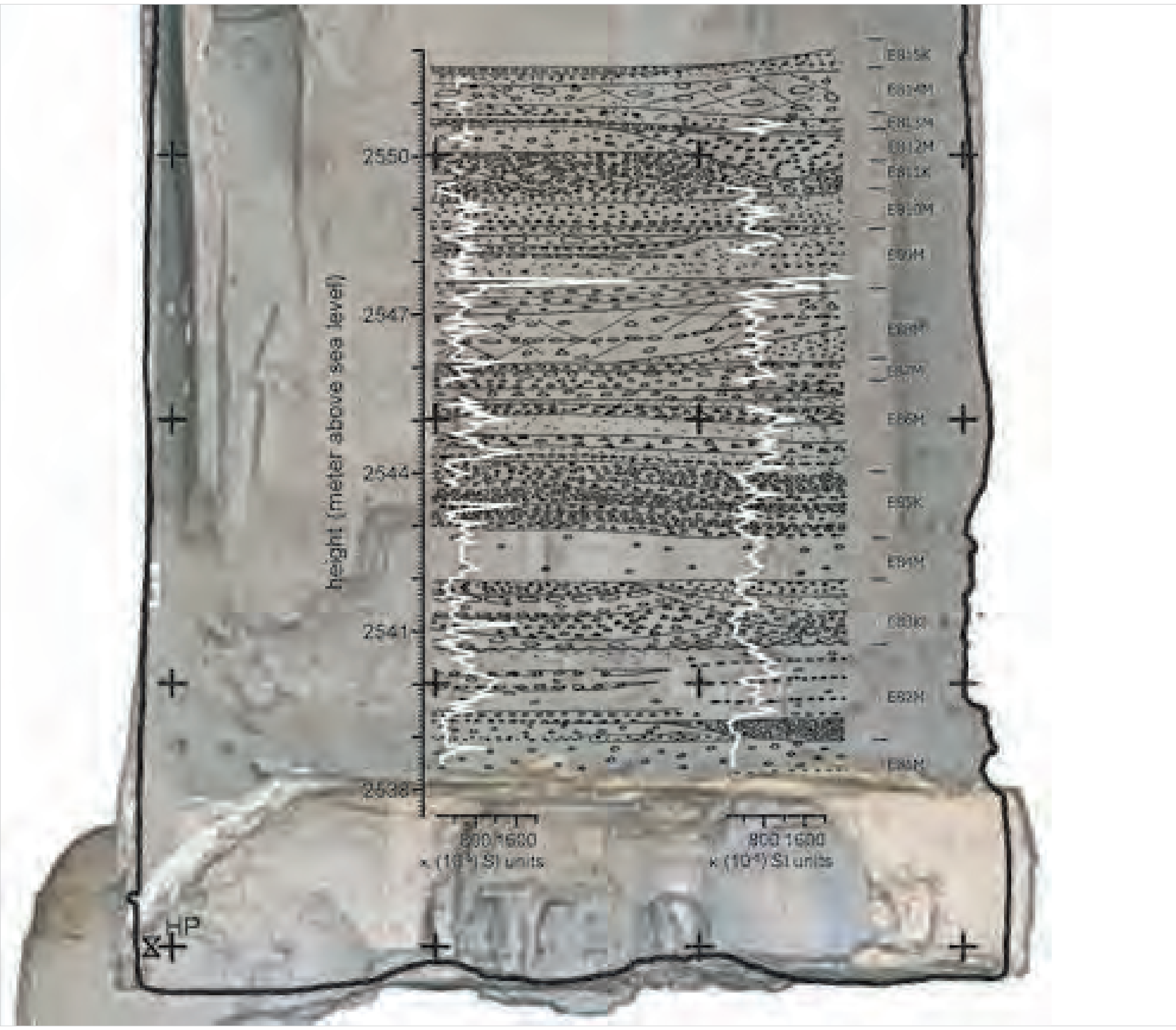

Fig. 4. Schematic of the eastern Buddha niche lithology indicating the results of the two magnetic susceptibility profiles. Major lithological units shown in more detail in figure 3. Height is in meters above sea level, profiles start at 2538.4 m.a.s.l. levelled from the reference point BP1 at 2535 m.a.s.l. Backgroung 3D scan is courtesy of RWTH Aachen group.

Clearly, while the general trends are readily correlative in between the two measured lines, within unit variation is high as would be expected as a consequence of the lateral variability of the units. Yet, individual lithological layers are always reflected by κ - in favour of the pattern matching approach.

Only few lithological units indicate that the measurement of magnetic susceptibility is not appropriate (fig. 4), because the size of the clasts exceeds several cm and matrix is absent or too minor. Given the random distribution of clasts, each of them having an individual magnetic susceptibility though, any attempt to match the equally randomly sampled signal in a fragment would obviously be in vain (sections where there are no κ values in fig. 3).

While the susceptibilities of the scaffolding poles in fact are high (around 20000 x 10^{-5} SI units for material bought in Kabul, around 8000 x 10^{-5} SI units for 'Messerschmitt' poles) as compared to the rock our tests on site indicate that neither the cage like construction of the scaffold surrounding the fragments left within the niche nor the measurements of the back plane will be affected if the SM-30 is operated about 40 cm away from the nearest pole. The same note of caution applies to the compensation step within each measurement where the sensor is removed from the rock face.

Fragments Eastern Buddha, additional

Two larger fragments which remained inside the niche were surveyed geologically and paleomagnetically (KBF_015, KBF_0XX). As was stated for the back plane of the niche, individual layers can clearly be described and susceptibilities vary distinctly with indivdual lithological layers. Fragment KBF_015 is tentatively placed at 2544 m.a.s.l. on the left hand side of the niche (fig. 5). KBF_0XX likely originates from a higher part of the succession for which the reference pattern has not been completed yet. A third fragment was not further considered, because the only side displaying geological information was not accessible.

Conclusions and recommendations

The detailed geological survey of the lower half of the eastern back plane yielded, together with the two susceptibility lines with measurements taken every 5 cm, a supposedly sufficient reference pattern for the pattern matching approach. A division into 15 major lithological units (EB1M through EB15M) is proposed. The notable lateral and vertical variability of the sediment also indicates that the stabilities of lithological layers will be highly individual with respect to any position on the back plane of the Eastern (or Western) Buddha niche. As a rule-of-thumb decreasing natural cementation (with clast supported fabrics as an end member) is correlative with decreasing shear strength of the rock (some absolute numbers for prominent rock types in Fecker 2006).

It is strongly recommended to complete the detailed geological survey of the back wall before any further consolidation work is being considered. Any consolidation works done to the back plane of the niche might directly influence any future geological/rock magnetic work within that respective area and should be discussed beforehand.

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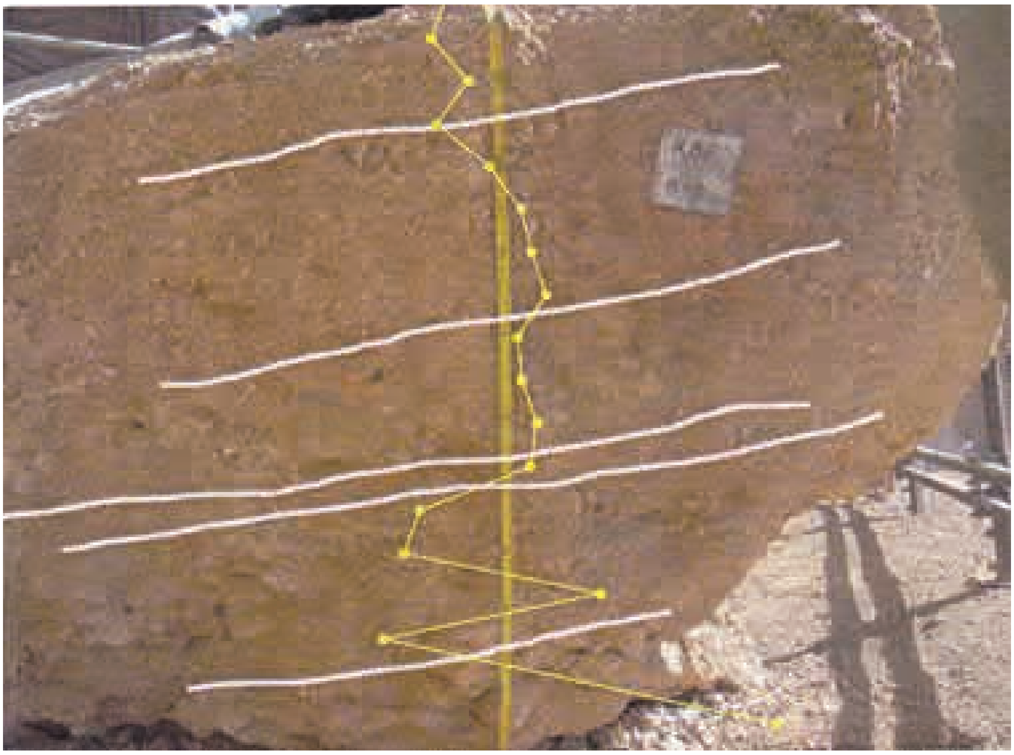

Fig. 5. Fragment KBF_015 from within the niche. White lines approximate prominent lithological layers, yellow curve displays magnetic susceptibility kin 10–5 SI Units. Vertical dimension of the fragment is 1.2 meters.