

III. EARTH BUILDING TRADITIONS IN BASGO AND LIKIR / LADAKH

1. INTRODUCTION

Within the field of material culture, the determination of material properties by examination of an object's single components is an essential aspect for proving the quality of the raw material, verifying places of origin, and understanding methods of processing. In the Himalayas, clay is still an important building material. The material characteristics of different types of clay and processing techniques follow traditional and locally defined patterns. Local knowledge on particular properties of clay, based on local experience, overlaps with regional knowledge with particular local adaptations. Today, general knowledge on locally available types of clay and processing practises is decreasing, and it is primarily various elders, who keep such information.

In researching this topic for the last 20 years, the author has collected and documented samples of clay from various sites in the Himalayas. These samples are the carriers of information on particular material qualities related to the use of specific material for different constructive purposes. The samples are either raw material collected from locally known pits known for their uses for specific building purpose or originate from damaged parts of certain building components. According to their material properties, they were analysed and compared. For comparison, material-specific properties, such as colour, grain size distribution, grain shape, hardness, organic additives and mineral properties were analysed and juxtaposed. Individual properties are examined in relation to their constructive uses. In the present study, locally used materials for adobe bricks, flat earth roof constructions, rammed earth floors, clay plaster, pottery and also the *thab* (Tibetan stove) are analysed. Some of the samples, in particular those of plasters and bricks, are related to historical sites; others are related to recent constructions and crafts. Traceable material properties were analysed based on analytic parameters – constructively and material-orientated. For the single techniques of construction, the results of the laboratory tests are juxtaposed, and analysed and additional examinations of selected samples were conducted. The analysis follows a categorisation specifically given by the single techniques, the place of material origin, and the local names of the raw material.

1.1 Research questions

Regarding the wide field of this study, the following research questions are posed with a primary focus on material research:

- What are the particular properties used to categorise specific commonly used earth building materials? What are the material properties, which support a particular building material's use for the building purposes mentioned?
- If there are any regional relations in the knowledge transfer about a particular material, in what way can they be related to specific locally conventional terms?
- In what way are building techniques and crafts related to each other and how can the knowledge gained be useful for future applications?

1.2 Origin of the samples

Samples originate from clay pits or particular parts of buildings, such as the roof, interior and exterior plaster, adobe bricks or rammed earth walls. Many of the clay pits are difficult to find without local help, as they are often integrated into the surrounding natural environment such as agriculturally utilized fields. The choice of particular samples is to a certain extent dependent on factors such as proper information from the local population, accessibility of the pit or object, and, if needed, particular local permission. Samples of loose earthen debris lying on the ground at various spots along building structures were collected without digging or applying any invasive impact on the structures.

As far as the collected type of samples has a particular local designation, all names were documented, same as the recording of the particular use and processing of each material. The sampling points were documented on a map and by photographs. The collected samples give a unique outline of clay as material used for building and crafts. The aim of such a variety is to keep a wide range of comparable samples with high diversity.

For the next chapter on building traditions in Basgo and Likir in Ladakh, samples were collected in these two villages, which are located about 10 km from each other along the Leh-Kargil Highway NH 1D (Map 3.1) at an altitude of app. 3,200 m and above. Over the course of field research, Basgo, Likir and the surrounding settlements stood out due to their wide range of different locally available and still used types of clay and living clay traditions. For several of the locally known types of clay, local names were available, which could be linked to a particular use or meaning within the field of building techniques.

In Basgo, several temples of different ages were built on top and along the foot of the temple-hill and also in the close vicinity to Basgo. For building purposes, the local tradition differentiates between clay used for roof constructions, interior and exterior plaster, and the plaster applied to pillars and bricks. Particular mixtures are known for particular building purposes, and the related raw material was collected for examination. For construction of a Tibetan clay stove (Tib. *thab sa*, which is a proper clay for building a clay stove), local knowledge still exists, and related samples of different kinds of clay were collected. Likir is well known as a village with a pottery tradition, and is further known as a source for not only pottery clay, but for good quality clay for building purposes. This functional interrelation between the properties of clay for different kinds of uses within one village, and even more so between these two villages, is the aim of this observation.

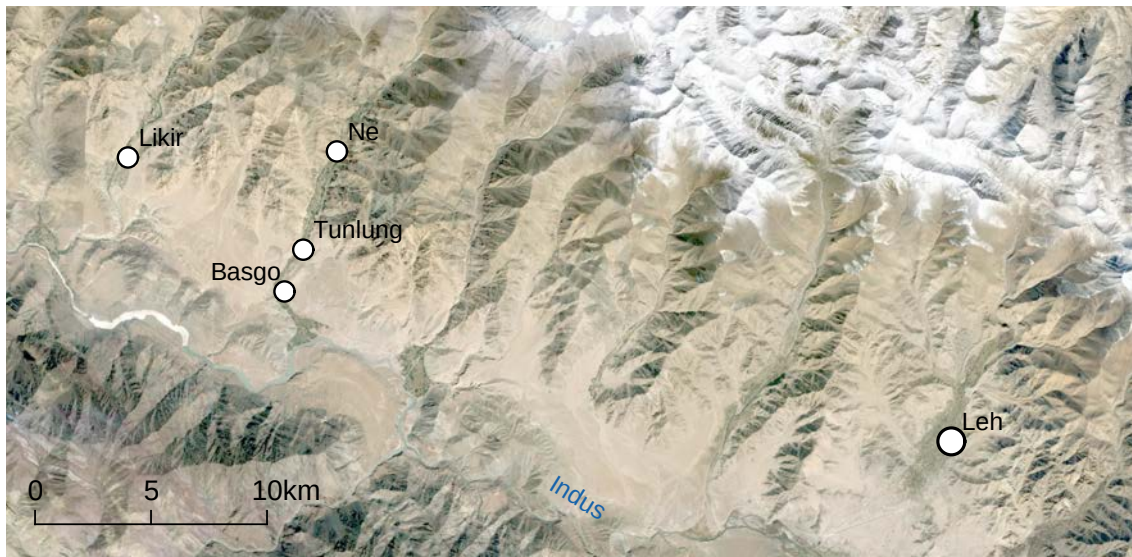
Several of the samples were collected at building structures at Basgo, as shown in Map 3.2. According to Table 1, the samples of the following structures will be examined:

Basgo: Maitreya Lhakhang, Lotsāba Lhakhang, Lhakhang ‘close to the road’ (Leh-Kargil Highway NH 1D), building raw material, clay stove (Tib. *thab*).

Basgo / Likir: Stove and pottery clay. Likir: Adobe brick, clay pit and sand.



Map 3.1 Basgo and Likir. Origin of the samples. GIS data based map: Jakob Gredler. Final graphics: author.
Map based on: Google Earth. Image © 2016 TerraMetrics.



Map 3.2 Building structures at Basgo related to the examined samples. GIS data based map: Jakob Gredler.
Final graphics: author. Map based on: Google Earth. Image © 2016 TerraMetrics.

Table 3.1 List of the samples.

Sample	Country	Province/prefecture	Settlement	Origin	Local name
Basgo – Maitreya Lhakhang					
8469	India	Ladakh	Basgo	plaster on pillar	---
8479	India	Ladakh	Basgo	plaster on pillar	---
8496	India	Ladakh	Basgo	int. wall plaster	---
Basgo – Lotsāba Lhakhang					
8482	India	Ladakh	Basgo	int. wall plaster	---
8483	India	Ladakh	Basgo	int. wall plaster	---
11946	India	Ladakh	Basgo	int. wall plaster	---
11948	India	Ladakh	Basgo	adobe brick	---
Basgo – Lhakhang close to road (Highway NH1D)					
8475	India	Ladakh	Basgo	int. wall plaster	---
11928	India	Ladakh	Basgo	int. wall plaster	---
8499	India	Ladakh	Basgo	ext. wall plaster	---
8472	India	Ladakh	Basgo	adobe brick	---
11933	India	Ladakh	Basgo	adobe brick	---
Basgo – building raw material					
15410	India	Ladakh	Basgo	clay pit	<i>dzasa</i> , red clay
11915	India	Ladakh	Basgo	clay pit	<i>thetsa</i>
15411	India	Ladakh	Basgo	clay pit	<i>thetsa</i>
8465	India	Ladakh	Basgo	clay pit	<i>thetsa</i> + <i>dzasa</i>
11952	India	Ladakh	Basgo	adobe brick	---
Basgo – clay stove (<i>thab</i>)					
11748	India	Ladakh	Tunlung	clay pit	<i>thabsa</i>
15412	India	Ladakh	Tunlung	clay pit	<i>thabsa</i>
11919	India	Ladakh	Ne	clay pit	<i>thabsa</i>
Basgo / Likir – stove and pottery clay					
15515	India	Ladakh	Basgo	clay pit/cave	<i>thabsa</i>
11751	India	Ladakh	Likir	clay pit	<i>thabsa</i> , <i>dzasa</i>
11752	India	Ladakh	Likir	clay pit	<i>dzasa</i>
Likir – adobe brick and clay pit					
11763	India	Ladakh	Likir	adobe bricks	---
11921	India	Ladakh	Likir	clay pit	---
Likir – sand					
11749	India	Ladakh	Likir	sand pit	<i>jema</i> (Tib.)

1.3 Structure of this chapter

Part 1: Mineralogical analysis of the clay samples.

Part 2: Additional examinations on selected samples.

Part 3: Discussion.

Grain size classes and results of bulk and clay mineral analysis are given in Tables 3.2, 3.3 and 3.4 at the end of Part 2 of this chapter. Further tables, graphics and related documents are attached in the Appendix of Chapter III.

2. RESEARCH METHOD

2.1 Documentation

During the expeditions the samples were numbered, catalogued and described in detail. Before examining the samples in the laboratory of the IAG / BOKU (Institute of Applied Geology / University of Natural Resources and Life Sciences in Vienna), they were numbered once more. The label of the samples in this text is related to this numbering at the laboratory, and for further identification in the text, the samples are listed in a table (Table 3.1).

The following parameters are part of the research on site:

- Locally specific names of the samples: Local names of specific types of clay were used for further identification of the particular material, since the names may indicate a certain location of where to find the clay or give information about a certain material quality. Local names were not existent for all types of clay. For further identification of each sample, the number entered in the book of samples will always enable its identification related to any further test.
- Description of where material was found: Contains the region, the place's name, the name and type of building and the location within the building. In the case of material collected at clay pits, the location of the pit is described and the locally known use of the material documented.
- General description of the material appearance of the samples, such as colour, taste and smell, haptic perception, grain size, and additives used: These parameters follow a testing with all senses, primarily conducted on site. The importance of citing such parameters lies in the practical importance for the builder, who is not primarily confronted with scientific data but with what can be immediately perceived about the material properties on site.
- General description of constructions: Local earth building traditions are documented descriptively. Their features are described, and structures as a whole and in detail will be visualised as drawings, plans and photographs. For proper analysis, the following documentation is required:
 - Architectural survey
 - Description of the natural environment
 - Description of the constructions and the materials' processing
 - Plans (ground plans, sections, elevations)
 - Drawings of the technical properties and details
 - Photographs
 - GPS position of the single objects
 - Interviews and local reports on the use and processing of building materials

- Constructions: Based on the collected material, examinations were conducted regarding the choice of the material for particular constructions and the material's particular processing. Technical parameters of the constructive typologies and their dependence on particular clay are discussed. Analysis focuses on the following points:
 - Detailed observation of the single constructions and crafts
 - Comparative constructive traditions
 - Technical properties
 - Local particularities
 - Impact of the natural environment on the use of these constructions
 - Possible relation between the use of a particular clay and the type of construction

2.2 Laboratory methods⁸⁹

2.2.1 Grain size analysis (GSA)

Particle size analysis was carried out as a combination of wet sieving (fractions $>20\ \mu\text{m}$) along with sedimentation analysis with Micromeritics Sedigraph III (fractions $<20\ \mu\text{m}$). 50 g of air-dried clay was treated for dispersion and destruction of organic substances over several days with app. 200 ml of 10% hydrogen peroxide. After completion of the reaction, excess oxygen was removed by boiling in a water bath. After sonication, the sample was sieved. Residues of sieving ($>2,000\ \mu\text{m}$, $>630\ \mu\text{m}$, $>200\ \mu\text{m}$, $>63\ \mu\text{m}$ and $>20\ \mu\text{m}$) were dried and weighed. The fraction $<20\ \mu\text{m}$ is used for the sedimentation analysis in the sedigraph after sonication. Results from sieving and sedigraph are combined.

2.2.2 Grain shapes

Grain shapes are determined according to Tucker (1985:17, 18) according to the following code:

0	very angular
1	angular
2	angular with beginning rounding
3	slightly rounded
4	rounded
5	well-rounded

2.2.3 Bulk mineral analysis (BMA) by XRD

Evaluation of an average amount of certain minerals is conducted according to peak intensity in relation to the general peak intensity. The intensities in the BMA tables are given with the following categorisation. Attention is also paid to amounts that deviate from the average. This semi-quantitative evaluation is given in proportional relation of the samples to each other. Since calcite and gypsum can be added for strengthening constructive features of particular clay mixtures, their amount is given quantitatively with the following symbols: . = traces, * = small amount, ** = medium amount, and *** = high amount. To determine the bulk mineral content, the samples were dried at 70°C and ground to a flour-like consistency ($\leq 20\ \mu\text{m}$) in a vibratory disc mill. The ground powder was prepared in a 'backload' procedure. Until 2010 X-ray analysis was conducted using a Philips X-ray diffractometer PW 1710 with a divergence slit (Cu-K α -rays (45kv, 40mA) 2° to 70° 2θ , 1 step per second, step size 0.02° 2θ). The semi-quantitative determination

⁸⁹ The description of laboratory methods is based on the methods given by Karin Wriesnig (2013: 57, 58 and 60).

of mineral contents was conducted according to Schultz (1964). For samples analysed after 2010, a Panalytical XPert Pro MpD diffractometer with automatic divergent slit, Cu LFF tube 45 kV, 40 mA, and an X'Celerator detector was used. The measuring time was 25s, with a step size of $0.017^\circ 2\theta$. Using a Scheibler apparatus, the content of carbonate was measured according to Ö-Norm L 1084 by destroying the carbonates with 15% HCl and determining the volume of the CO_2 in consideration of air pressure and temperature. The inorganic content of carbon was calculated by multiplying the content of carbonate by 0.12.

2.2.4 Clay mineral analysis (CMA)

The sample preparation was carried out according to Whittig (1965) and Tributh (1970). The destruction of organic substances was the same as with the GSA. The preparation of the sample was conducted in parallel to the GSA. The clay fraction was a result of centrifugating (five minutes at 1,000 rpm) from the $<20\ \mu\text{m}$ fraction. The complex of sorption of the clay fraction was exchanged by shaking with 4 N MgCl_2 or 4 N KCl solutions, respectively. An X-ray analysis was conducted using a Philips X-ray diffractometer PW 1710 until 2010, and with a Panalytical XPert Pro MpD diffractometer after 2010 (as described before). Each porous ceramic plate carries 20 mg of clay (Kinter, Diamond 1956). These texture specimens were dried over night in a dessicator above a saturated NH_4NO_3 -solution before being X-rayed. Thereafter, for the determination of swellable clay minerals (smectite, vermiculite), all ceramic plates were put into an atmosphere saturated with ethylene glycol. Subsequently, for the identification of well-crystallised kaolinite, these plates, which had already been prepared with potassium, were additionally treated with dimethyl sulfoxide (DMSO). In addition to this process, the plates were tempered at 550°C for two hours to determine primary chlorite. After each treatment the samples were X-rayed (K and Mg plates from 2° to $40^\circ 2\theta$, with ethylene glycol treated plates from 2° to $32^\circ 2\theta$, with dimethyl sulfoxide (DMSO) treated plates from 2° to $26^\circ 2\theta$, and tempered plates from 2° to $14^\circ 2\theta$). The identification of clay minerals is conducted according to Thorez (1975), Brown (1980), Moore & Reynolds (1989) and Wilson (1987). For the semi-quantitative evaluation, the areas of characteristic peaks in combination with empirical correction factors were used (Riedmüller 1978). The untreated remaining clay fraction is freeze-dried for further investigation.

2.2.5 Simultaneous Thermal Analysis (STA)

50 mg of the grounded and at a relative humidity of 65% equilibrated sample were heated from 25°C to $1,000^\circ\text{C}$ in a Pt-Rh crucible at a heating rate of 10°K per minute. Measurement was conducted using an instrument of Netsch (Luxx 429) at a flow of 15 ml of nitrogen and 50 ml air per minute. As a correction, an empty crucible was used. STA results were used for the determination of the content of gypsum and calcite. Several peaks resulting from an endothermic or exothermic process were typical for most of the samples and not additionally quoted.

- a peak at around 75°C points towards the escape of adhesive water.
- a peak at around 120°C to 180°C indicates the escape of water of crystallising gypsum.
- a peak at around 350°C to 450°C indicates the combustion of organic material.
- a peak at around 573°C points towards quartz inversion.
- a peak at around 750°C shows the release of CO_2 from carbonate minerals.

2.2.6 Infrared Spectroscopy (IRS)

Compacted samples were composed of 250 mg potassium bromide and 1 mg clay, or 1 mg of grounded and at 70°C dried clay. IR-spectra were measured with a Bruker spectrometer Tensor 27 between wave numbers 4,000 cm^{-1} and 500 cm^{-1} .

2.2.7 Sample colours

Sample colours were determined in a dry and semi-dry state according to the Munsell Soil Colour Chart. In the following detailed mentioning of the single samples' colours, further explanation is only given in the case of deviation from the average appearance of samples within one region. For the determination, the colours in the chart mentioned with the appendix YR (Yellow-Red) are used. Munsell categorises between five hues: R (Red), Y (Yellow), G (Green), B (Blue) and P (Purple); and intermediate hues: YR, GY (Green-Yellow), BG (Blue-Green), PB (Purple-Blue) and RP (Red-Purple). The resulting ten hues are again divided into ten increments, in total resulting in 100 hues. Practically, only forty are used, containing four charts titled as 2.5, 5, 7.5 and 10. The two following numbers, which are divided by a dash, categorise the lightness between 0 (black) and 10 (white) and the chroma, which is measured radially. The 10YR chart most often used within the current research, followed by 7.5YR. This designation is followed by two numbers, e.g. 10YR 5/2. The first number ranges between 0 (absolute black) and 10 (absolute white), and the second number indicates clay colour ranges app. between 2 and 8 in the current research. For all samples, the dry and also semi-dry colours were measured.

2.2.8 Shrinkage

The value of the geological shrinkage refers to the weight of the humid sample as 100%, while the geotechnical shrinkage refers to the dried sample as 100%. In the following, geotechnical shrinkage is given.

3. MINERALOGICAL ANALYSIS OF CLAY SAMPLES

BASGO – MAITREYA LHAKHANG. SAMPLE 8469



Fig. 3.1 (Left) Basgo. Palace and monastery. Picture on the top right: Maitreya Lhakhang.
Fig. 3.2 (Right) Basgo. Maitreya Lhakhang with plastered round-shaped pillars.

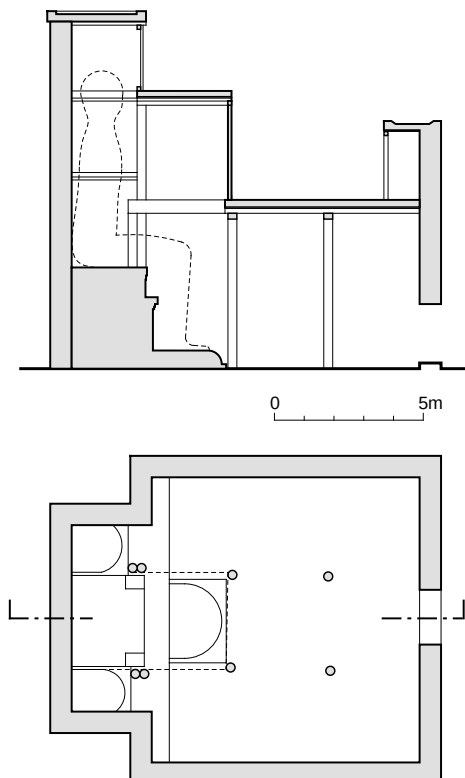


Fig. 3.3 (Left) Basgo. Maitreya Lhakhang. Ground plan and section. The ground plan shows the position of the round-shaped pillars.

Fig. 3.4 (Right) Basgo. Maitreya Lhakhang. Damage at the plaster on a pillar.

Sampling point

Ladakh, Basgo, Maitreya Lhakhang (upper temple), located app. at 34°13'27.62"N, 77°16'36.22"E (see Map 3.2, Figs. 3.1 to 3.3). The name of this temple follows a locally common designation. The pillars are plastered and painted red. Debris was collected by a worker from the floor during renovation work, originating from a deep crack in the plaster of a pillar (Fig. 3.4). The plaster is composed of two layers, a levelling (lower) layer and an upper layer, on which the red paint was applied. This sample belongs to the levelling layer (= ground layer), which was applied onto and between a rope-like bunch of fibres. The rope has a diameter of app. 1 cm and was helically twisted around the wooden pillars (Fig. 3.5). In Ladakh, plastering of a wooden pillar is a rarely used technique. Commonly, wooden pillars, which are round or angular, are directly painted but not plastered. The diameter of these pillars including the plaster is app. 30 cm, and the plastering was conducted along the full height of the pillar at app. 5.30 m. The thickness of the full plaster compound is app. 3 cm to 4 cm, and the thickness of the levelling layer is app. 2 cm. Sample number in the field: 34 BA/IP II. Additives: Straw with a length of up to 3 cm is present in a small amount. Constructive use: Levelling layer of plaster on a round wooden pillar. The organic fibres originate from the *busho* grass, which grows in the fields of Basgo. It becomes elastic when moistened, and reaches lengths of up to three metres. Furthermore, this grass is known for being twisted into a rope. Today it is used as animal feed and for making fire. June and July are the best months to harvest this grass.



Fig. 3.5 (Left) Basgo. Maitreya Lhakhang. Fibres visible due to a damage of the plaster.

Grain size distribution

As a plaster levelling layer, the material is relatively fine (biggest fraction: fine gravel). The median is located at app. 22.0 μm ; the $<2 \mu\text{m}$ fraction contains app. 12% of the whole sample. Fractions $>20 \mu\text{m}$ amount to about 88% of the whole material. The maximum peak is 20.4% medium silt, and the whole sample is dominated by the silt and sand fractions. The sharp break in the grain size distribution between fine silt and coarse clay points towards the addition of coarse material or the desludging of fine material to avoid cracks.

	Gravel	Sand	Silt	Clay [%]
8469	0.8	32.2	55.2	11.8

Grain shapes

Grain size is up to 8 mm. Grain shapes $>2,000 \mu\text{m}$ and also between $40 \mu\text{m}$ and $2,000 \mu\text{m}$ are dominantly 'angular-shaped'. This fact does not support the hypothesis that the material can be a mixture of two different types of clay (Fig. 3.6).

Bulk mineral analysis

The sample contains a small amount of amphiboles, 7Å minerals, phyllo silicates, quartz, K-feldspar, plagioclase and calcite, but no gypsum. 14Å minerals, mica and hematite are present in trace amounts. The content of calcite is 8%.

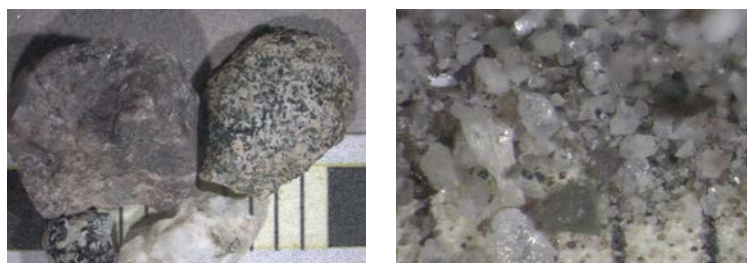


Fig. 3.6 Shape of grains in sample 8469. Scaled in millimetre. Shape of fraction >2,000 µm (left), 40–2,000 µm (right).

Clay mineral analysis

The CMA shows a scattered content of clay minerals. Comparison with other samples shows this sample to be equal with sample 8479, i.e. the sample of the upper layer of the plaster in the Maitreya Lhakhang. This indicates that for the levelling plaster of the pillar and the interior wall plaster, the same material (possibly from the same pit) was used (see sample 8496). At 44% (of the clay fraction), the sample shows a relatively high content of swellable clay minerals (22% smectite and 22% vermiculite). According to most of the samples within this region, the content of kaolinite is rather low.

	Smectite	Verm18°	Illite	Kaolinite	Chlorite [%]
8469	22	22	37	3	16

BASGO – MAITREYA LHAKHANG. SAMPLE 8479

Sampling point

Ladakh, Basgo, Maitreya Lhakhang (upper temple). Debris was collected by a worker from the floor during renovation work, originating from along a deep crack in the plaster of a round and red coloured pillar (like sample 8469 located app. at 34°13'27.62"N, 77°16'36.22"E). The plaster is composed of two layers: the levelling (lower) layer and the upper layer, on which the red paint was applied. The thickness of the red-painted upper layer is app. 1.5 cm. This sample is related to sample 8469 (levelling plaster on a pillar) and is the second and upper fine plaster layer not reinforced with fibres like the levelling layer. Sample number in the field: 38 BA/IP IV. Constructive use: Upper layer of a pillar plaster.

Grain size distribution

The material is relatively fine, with the biggest fraction being fine gravel. The median is located at app. 70 µm; the <2 µm fraction contains app. 17% of the whole sample. Fractions >20 µm together make up about 81% of the whole material. The maximum peak is 19.6% medium sand, and the whole sample is dominated by sand followed by silt and clay fractions. Interestingly, the fine layer is coarser than the levelling layer. An explanation for this may be the fact that the less coarse material in the levelling layer adheres better to the fibres below than the coarse material. Since

the amount of swellable clay minerals (smectite and vermiculite) is relatively high, the addition of sand seems to be useful against cracking. Nevertheless, the 2 μm fraction is with 17% more present as is the case in the levelling layer. The grain size distribution graphics do not show such an immediate break between silt and clay, as is the case in the levelling layer. This would point towards a reduction of the fine material by desludging of the levelling material but an addition of coarse material in the sand and fine gravel fractions.

	Gravel	Sand	Silt	Clay [%]
8479 (upper plaster)	2.7	48.9	31.8	16.6
8469 (ground plaster)	0.8	32.2	5.2	11.8

Grain shapes

The grain size is up to 4 mm. Grain shapes $>2,000 \mu\text{m}$ are ‘angular-shaped’ and partially show ‘beginning rounding’ (Fig. 3.7), while for the fractions below, primarily ‘angular-shaped’ grains are available. Compared with the coarse layer from sample 8469, an additional grain shape appears in the gravel fraction with a finer shape towards ‘beginning rounding’. The ‘angular-shaped’ material becomes less in the finer upper layer. This fact may emphasise the hypothesis of separating the very coarse and adding finer material for the upper plaster layer.



Fig. 3.7 Shape of grains in sample 8479.
Shape of fraction $>2,000 \mu\text{m}$.

Bulk mineral analysis

The BMA shows mineral contents very similar to sample 8469, with just a slightly higher content of quartz and plagioclase. The content of calcite is 11%, as shown in Table 3 given at the end of this chapter. It was possibly used as a base layer before the addition of red paint. The colours, particularly in a semi-dry state, are the same in the samples 8469 and 8479. Traces of hematite explain the light reddish colour, though not the red paint as shown in the picture.

Clay mineral analysis

The CMA shows a scattered content of the clay minerals, similar to sample 8469. The much higher content of illite is a striking difference.

	Smectite	Vermi18°	Illite	Kaolinite	Chlorite [%]
8479	18	16	52	0	14

Additives

Straw with a length of up to 1 cm is minimally present. The content of straw seems less than we find in the levelling layer, and the fibres are much shorter.

BASGO – MAITREYA LHAKHANG. SAMPLE 8496

Sampling point

Debris was collected by a worker from the floor during renovation work, originating from a deep crack along the left wall (view towards central statue). The thickness of the full plaster compound was app. 3 cm. Sample number in the field: 36 BA/LS. Constructive use: Interior plaster on the left wall in the assembly hall. Additives: A small amount of fine fibres of straw and small pieces of wood are present, though not as coarse as found in samples 8469 and 8479. Thus a different way of processing between the plasters used on the pillars and the plaster used on the wall is shown.

Grain size distribution

The material is relatively coarse, with the biggest fraction composed of medium gravel. The median is located at app. 130 μm ; the $<2\ \mu\text{m}$ fraction contains app. 11% of the whole sample. These data are similar to levelling plaster 8469. A big difference is the high content of coarse material in sample 8496, in particular a high amount of coarse sand and fine gravel as well as medium gravel. Fractions $>20\ \mu\text{m}$ together make up about 89% of the whole material, which is also similar to sample 8469. The whole sample is dominated by the sand fraction followed by silt and clay fractions. Also in this case, the amount of swellable clay minerals (smectite and vermiculite) is relatively high, and the addition of sand seems to be useful against cracking. Since the basic material contains the whole plaster compound (levelling and fine plaster) and seems to be similar to what was used for the plaster of the pillars, this sample represents an average of the added data gathered at the pillar plaster samples 8469 and 8479.

Taking into account the fact that the CMA of samples of the Maitreya Lhakhang show a slight similarity to sample 8475 (plaster in the ‘Lhakhang close to the road’; explained in the following), grain size distributions will be compared. Regarding the median and 2 μm of samples 8475, 8469 and 8496, we state the following:

8469: The median is located at app. 20 μm ; the $<2\ \mu\text{m}$ fraction at app. 12%.

8496: The median is located at app. 130 μm ; the $<2\ \mu\text{m}$ fraction at app. 11%.

8475: The median is located at app. 20 μm ; the $<2\ \mu\text{m}$ fraction at app. 18%.

This comparison shows a close similarity between the grain size distributions of samples 8469 and 8475, while sample 8496, the interior wall plaster in the Maitreya Lhakhang, is much coarser.

	Gravel	Sand	Silt	Clay [%]
8496 (interior wall plaster)	17.3	41.9	30.0	10.8
8469 (levelling pillar plaster)	0.8	32.2	5.2	11.8
8479 (upper pillar plaster)	2.7	48.9	31.8	16.6
8475 (interior wall plaster)	6.5	33.1	42.6	17.8

Grain shapes

Grain shapes between 2,000 μm and 200 μm are dominantly ‘angular-shaped’, similar to sample 8479. This is possibly a result of desludging or separating the raw material and adding the leftover sand to the plaster.

Bulk mineral analysis

The BMA shows a mineral content similar to sample 8469, i.e. the levelling plaster in the Maitreya Lhakhang, but with a slightly higher content of K-feldspar and a much higher content of plagioclase. An 8% content of calcite is similar to the levelling layer 8469. An anthropogenic addition cannot be excluded, possibly as a base layer for the addition of red painting, or the use of a content of *martsī* (Tib.; is a red colour clay with a high content of calcite) for the red painting. *Martsī* shows a high content of calcite, which explains the slightly higher amount of calcite in sample 8479, i.e. the upper and finer plaster layer of the pillar. Compared with sample 8475, i.e. the interior wall plaster in the ‘Lhakhang close to the road’, similarity is found, though not as strong as with sample 8469, which is a material from the same temple. The colours, particularly in the semi-dry state, are similar for samples 8469, 8479 and 8496. Traces of hematite explain the light reddish colour.

Clay mineral analysis

The CMA shows a scattered content of the clay minerals. A difference in comparison to samples 8469 and 8479 (pillar plasters) is the much higher content of smectite (44% of the clay fraction) and swellable clay minerals (60% of the clay fraction), which makes this sample much more swellable. This justifies the higher amount of coarse material – particularly gravel – that acts against cracking. Regarding comparison with sample 8475 (plaster in the ‘Lhakhang close to the road’), similarities are obvious, pointing towards a similar basic material.

	Smectite	Verm18°	Illite	Kaolinite	Chlorite [%]
8496	44	16	24	0	16

BASGO – LOTSĀBA LHA KHANG. SAMPLE 8482

Sampling point

The Lotsāba Lhakhang is located at app. 34°13'26.64"N, 77°16'30.96"E. The name used for this Basgo temple follows a locally common designation. Remains of the interior upper plaster carry remnants of a white layer. The thickness of the whole plaster is 2.5 cm, and the thickness of the upper layer is app. 1 cm. Sample number in the field: 35 BA/IP III. Additives: Long pieces of straw up to 2 cm and also very short pieces (<2 mm) are present in small amounts. Constructive use: Interior wall plaster; upper layer (Figs. 3.8 to 3.11).

Grain size distribution

The material is relatively fine, with the biggest fraction being fine gravel (very small amount). The median is located at app. 5.5 µm; the <2 µm fraction contains app. 24% of the whole sample. At 62.5%, the silt content is relatively high and may be relevant for the compensation of the high content of swellable clay to avoid cracks. Fractions below 63 µm (silt and clay) together make up about 81% of the whole material. Silt and clay together compose 92.5% of the whole sample. The maximum peak clearly corresponds to medium and fine silt (together 56.7%). Since the amount of swellable clay minerals (smectite and vermiculite) is relatively high, the addition of sand seems to be useful against cracking. The grain size distribution graphics do not show an immediate break or a bimodal distribution – a possible evidence for the use of the desludging method and a lack of

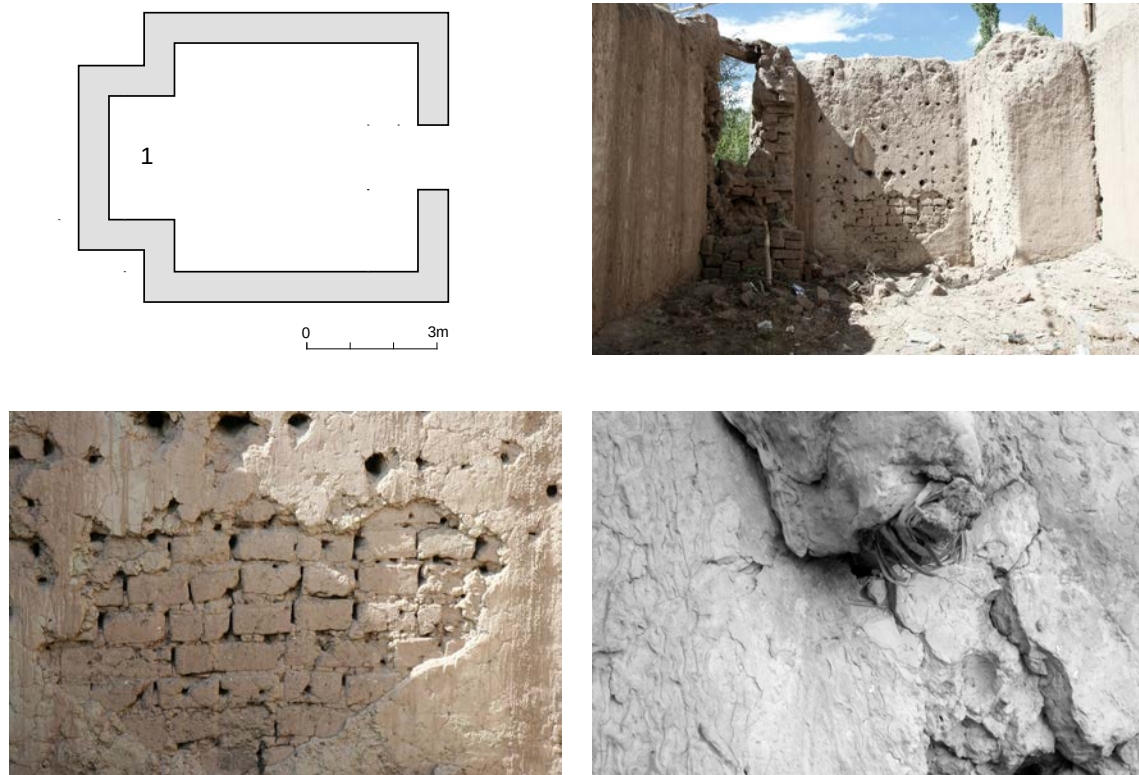


Fig. 3.8 (Top, left) Basgo. Lotsāba Lhakhang. Ground plan. 1 = *cella* niche.

Fig. 3.9 (Top, right) Basgo. Lotsāba Lhakhang. View towards *cella* niche.

Fig. 3.10 (Bottom, left) Basgo. Lotsāba Lhakhang. Brick bond.

Fig. 3.11 (Bottom, right) Basgo. Lotsāba Lhakhang. Layers of plaster next to a wooden bracket.

addition of coarse material. This is particularly seen when compared to the brick sample from the same wall (11948), which shows a much higher content of coarse material.

	Gravel	Sand	Silt	Clay [%]
8482 (upper layer incl. white layer)	0.5	7.0	67.7	24.8

Grain shapes

Grain shapes between 2,000 μm and 200 μm are dominantly ‘angular-shaped’ and give no evidence for the addition of another material.

Bulk mineral analysis

The sample contains a small amount of amphiboles, 7Å minerals, phyllo silicates, quartz, K-feldspar, plagioclase, and calcite. 14Å minerals, mica and hematite appear as traces – generally similar to samples 8469, 8479 and 8496. The content of calcite is 6%, as shown in Table 3. Compared to other Basgo samples, the content of calcite is evident in most of the samples and an average amount of app. 8% seems to be naturally given. Regarding this fact, the white layer seems to be the result of slight remains of a layer of gypsum, as shown in the BMA.

The content of gypsum was measured at 2%. A content of gypsum was also traced by X-ray diffraction within a slower measurement. Since there is no evidence of gypsum in sample 11946 (plaster without white coating) or sample 11948 (adobe brick) – both of which have a similar content of calcite – the hypothesis of a gypsum layer upon the plaster may be emphasised. The colours, particularly in the semi-dry state, are the same for samples 8465, 8469, 8496 and 8482. Traces of hematite explain the light reddish colour.

Results measured with STA

- A peak at 132°C points towards the transformation of gypsum to hemihydrate.
- A peak at 141°C points towards the transformation of hemihydrate to anhydrite.
- The residual mass at 1,000°C is 93.09%.

Clay mineral analysis

The CMA shows a scattered content of the clay minerals with a relatively high content of illite.

	Smectite	Verm18°	Illite	Kaolinite	Chlorite [%]
8482	9	14	51	4	22
8479	18	16	52	0	14
8465	18	11	51	4	16

The CMA of sample 8482 (plaster from the ‘Lotsāba Lhakhang’) shows similarities with samples 8479 (plaster on the pillar in the Maitreya Lhakhang) and 8465 (mixture for flat roof construction). At 23% of the clay fraction, smectite and vermiculite are similarly present as swellable minerals for sample 8482. This is lower than for samples 8479 and 8465 with 34% and 29%, respectively. The amount of illite is nearly the same, and the amount of kaolinite is in general small. Also the content of chlorite is rather similar to samples 8479 and 8465. All these samples do not really show a clear marker for their local assignment.

A comparison of the grain size distribution shows the interior plaster in the Lotsāba Lhakhang being by far the finest of the examined plasters, followed by the plaster on the pillar in the Maitreya Lhakhang and further by the material used for a flat roof. Regarding the content of clay, these three samples are relatively close to each other, in particular sample 8482 (interior plaster in the Lotsāba Lhakhang) and sample 8479 (material used for a flat roof).

- 8482: The median is located at app. 5.5 µm; the 2 µm fraction at app. 24%.
- 8479: The median is located at app. 70 µm; the 2µm fraction at app. 17%.
- 8465: Material used for a flat roof: The median is located at app. 210 µm; vs. 240 µm at sample 15411 (*thetsa* sand) and 2,000 µm at sample 15410 (*dzasa*); the 2 µm fraction is at app. 11%.

BASGO – LOTSĀBA LHAKHANG. SAMPLE 8483

Sampling point

Ladakh, Basgo, ruin of the Lotsāba Lhakhang, like sample 8482 it is located at app. 34°13’26.64”N, 77°16’30.96”E. Remains of the interior fine plaster carried remnants of a white layer (probably lime or gypsum). This sample was found in the same chamber as sample 8482 but along a different

section of the wall. The results are expected to be similar to those of sample 8482. The thickness of the upper layer is about 1 cm. Sample number in the field: 30 BA/IP. Additives: Long pieces of straw up to 1 cm and also very short pieces (<2 mm) are present in a relatively small amount, similar to sample 8482. Constructive use: Interior wall plaster; upper layer.

Grain size distribution

The material is relatively fine, with the biggest fraction being fine gravel (very small amount). The median is located at app. 4.8 μm ; the <2 μm fraction contains app. 26% of the whole sample (a quarter of the whole sample). At 64.9% the content of silt is relatively high and may be relevant for the compensation of the high content of swellable clay to avoid cracks. Fractions <63 μm (silt and clay) amount to about 91% of the whole material. The maximum peak corresponds to medium and fine silt, together equalling 56.3%. Since the amount of swellable clay minerals (smectite and vermiculite) is relatively high, the addition of sand seems to be useful against cracking. The grain size distribution graphics do not show an immediate break or valley between two fractions – a possible evidence for the use of the desludging method and lack of the addition of coarse material. This is seen in particular when compared to the brick sample from the same wall (11948), which shows a much higher content of coarse material.

	Gravel	Sand	Silt	Clay [%]
8483 (upper layer incl. white layer)	0.9	8.1	64.9	26.1
8482 (upper layer incl. white layer)	0.5	7.0	67.7	24.8

Grain shapes

The size of the grains is up to app. 7 mm. The grain shapes between 2,000 μm and 200 μm are dominantly ‘angular-shaped’ and give no evidence for the addition of another material. Desludging of the material cannot be excluded.

Bulk mineral analysis

The BMA shows more or less the same result as sample 8482, and emphasises the similarity between these two samples and the fact that for one interior plaster the same raw material qualities and refinements of the material were chosen. The content of calcite was measured at 6%. The content of gypsum was measured at 2%, same as for sample 8482. A content of gypsum was also traced in the X-ray diffraction as a result of a slower measurement. The colours, particularly in the semi-dry state, are the same for samples 8465, 8469, 8496, 8482 and 8483. Traces of hematite explain the light reddish colour.

Results measured with STA

- A peak of 137°C points to the transformation of gypsum to hemihydrate.
- The residual mass at 1,000°C is 89.69%.

Clay mineral analysis

The CMA shows a scattered content of the clay minerals with a relatively similar proportion of the single minerals compared with sample 8482. Only the amount of smectite strongly varies between 9% and 20% (of the clay fraction) – possibly due to the use of different layers within the clay pit or the use of material from clay pits close to each other.

	Smectite	Verm18°	Illite	Kaolinite	Chlorite [%]
8483	20	15	44	3	22
8482	9	14	51	4	22

BASGO – LOTSĀBA LHAKHANG. SAMPLE 11946

Sampling point

The ruin of the Lotsāba Lhakhang, like sample 8482, is located at app. 34°13'26.64"N, 77°16'30.96"E. Remains of the interior plaster (levelling and upper layer) carry no remnants of a white layer. This sample was found in the same chamber as samples 8482 and 8483 but at a different section of the wall. It contains a levelling layer and a fine upper layer. The thickness of the plaster is about 2.5 cm. Sample number in the field: 69. Additives: Straw of a length of up to 3 cm is present in a medium amount. Constructive use: Interior wall plaster; levelling and upper layer.

Grain size distribution

The material is relatively fine but in general coarser than samples 8481 and 8483 (previously examined); biggest fraction: medium and fine gravel. The median is located at app. 9 µm; the <2 µm fraction contains app. 17% of the whole sample. The content of silt at 62.9% is relatively high and may be relevant for the compensation of the high content of swellable clay to avoid cracks. Fractions <63 µm (silt and clay) amount to about 78.5% of the whole material. The maximum peak corresponds to medium and fine silt, with both together equalling 51.8%. The amount of swellable clay minerals (smectite; no vermiculite) is much less than for samples 8482 and 8483, which may indicate that the material for the interior plaster was not taken from only one particular pit and may have been added at a later time. The grain size distribution graphics do not show an immediate break or valley between two fractions – evidence for the use of the desludging method and lack of addition of coarse material. This may be seen in particular when compared to the brick sample from the same wall (sample 11948), which shows a much higher coarse content and a valley in the grain size classes, likely related to a material mixture. For this sample, a lesser content of clay and a higher content of sand may be due to a higher amount of parts of the levelling layer, a similarity to samples 8482 and 8483.

	Gravel	Sand	Silt	Clay [%]
11946 (full plaster without white layer)	5.2	16.3	62.9	15.6
8482 (upper layer incl. white layer)	0.5	7.0	67.7	24.8
8483 (upper layer incl. white layer)	0.9	8.1	64.9	26.1

Grain shapes

Grain shapes between 200 µm and 6,300 µm are dominantly 'angular-shaped' with a tendency towards 'angular with beginning rounding', which occurs fluently as opposed to abruptly (Fig. 3.12). This fact emphasises the hypothesis that the addition of another material was probably not relevant, but possibly desludging and the addition of desludged material may have had an impact.

Bulk mineral analysis

The BMA shows more or less the same result as samples 8482 and 8483, and emphasises its similarity and the fact that for one interior plaster the same raw material qualities and refinements of the material were chosen. Contrary to samples 8482 and 8483, gypsum is present only in trace amounts, which may indicate the use of gypsum for the upper layer as a base for mural paintings. The content of calcite follows with 10% the average indicated amount of calcite within the Basgo samples. No gypsum is present. The colour of this sample varies slightly from the samples before due to its higher content of coarse material and shows a tendency towards grey with no red, same as the previous samples. This is also due to the absence of hematite.

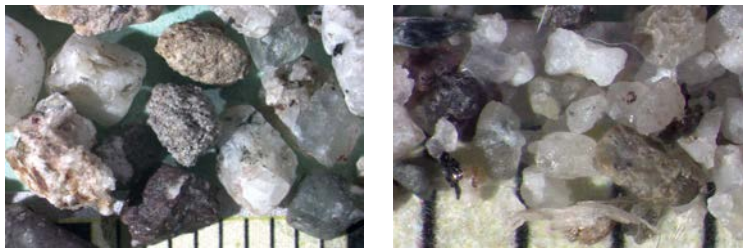


Fig. 3.12 Shapes of grains in sample 11946. Scaled in millimetre. Shape of fraction $>2,000\ \mu\text{m}$ (left), $>200\ \mu\text{m}$ (right).

Clay mineral analysis

The CMA shows a scattered content of the clay minerals with a relatively similar proportion of the single minerals to samples 8482 and 8483. It shows similarities to the CMA of samples 8482 and 8483 but also clear differences, like a smaller content of smectite, the lack of vermiculite and a higher content of illite (65% of the clay fraction), both of which might indicate the use of a different clay pit. At 6%, the amount of swellable material is comparatively low.

	Smectite	Verm18°	Illite	Kaolinite	Chlorite [%]
11946	6	0	65	2	26
8482	9	14	51	4	22
8483	20	15	44	3	22

BASGO – LOTSĀBA LHAKHANG. SAMPLE 11948

Sampling point

Ladakh, Basgo, ruin of the Lotsāba Lhakhang, like sample 8482, it is located at app. $34^{\circ}13'26.64''\text{N}$, $77^{\circ}16'30.96''\text{E}$. Sample of an adobe brick found along the rear wall. Sample number in the field: 68. Additives: Pieces of straw up to a length of app. 3 cm as well as very short pieces are present. In this area, it is rare to find straw content within an adobe brick. Constructive use: Adobe brick.

Grain size distribution

The material is relatively coarse, particularly when compared to plaster samples 8482, 8483 and 11946; biggest fraction: fine gravel. Compared with interior plaster sample 11946, no medium gravel is available. The median is located at app. $220\ \mu\text{m}$; the $<2\ \mu\text{m}$ fraction contains app. 10% of the whole sample. Together equaling 68.3%, the content of gravel and sand together is relatively high and may be relevant for the compensation of the amount of swellable clay minerals (28%

smectite of the clay fraction). Additionally, it clearly shows a distinction between plaster and brick material. For binding a content of about 10% $<2\ \mu\text{m}$ is needed. The grain size distribution graphics show a bimodal distribution between fine gravel and medium sand – possible evidence for mixture with another material. In the case of the brick, the material is much more equal to the raw material or the added coarse material.

	Gravel	Sand	Silt	Clay [%]
11948 (adobe brick)	17.2	51.0	21.8	10.0
8482 (upper layer incl. white layer)	0.5	7.0	67.7	24.8
11946 (full plaster without white layer)	5.2	16.3	62.9	15.6

Grain shapes

The size of the grains is up to 2 cm. Grain shapes $>6,300\ \mu\text{m}$ and $>2000\ \mu\text{m}$ show ‘beginning rounding’ and are also ‘angular-shaped’, while for fractions below $200\ \mu\text{m}$, ‘angular-shaped’ is dominant. This change in shape at around $2,000\ \mu\text{m}$ may be an indication of the addition of coarse material (Fig. 3.13).



Fig. 3.13 Shapes of grains in sample 11948. Scaled in millimetre.
Shape of fraction $>2,000\ \mu\text{m}$ (left), $>630\ \mu\text{m}$ (centre), $>200\ \mu\text{m}$ (right).

Bulk mineral analysis

The BMA shows similar results to plaster samples 8482, 8483 and 11946 with slightly less amphiboles. Also present is an 11% content of calcite, which follows the average amount of calcite found within the Basgo samples. No gypsum is present. Traces of hematite explain the light red-dish colour. As a darker sample, this sample differs from samples 8482, 8483 and 11946.

Clay mineral analysis

The CMA shows a scattered content of the clay minerals with relatively few similarities amongst the single minerals compared with samples 8482, 8483, 11946 and 11948. Apart from similarities, it also shows clear differences like the higher amount of smectite. However, similar to plaster 11946, there are no indications of a content of vermiculite. The amount of illite, in contrast, is similar to plaster samples 8482 and 8483 but differs from plaster sample 11946, which stands out at 65% of the clay fraction. Within all Basgo-Likir samples, two further samples, i.e. 11752 and 11952, show similarities to sample 11948 (as shown below). These similarities are no vermiculite and a strongly marked chlorite. The differences between samples 11946 (interior plaster) and 11948 (adobe brick) result in a different geological mechanism of transport.

	Smectite	Verm18°	Illite	Kaolinite	Chlorite [%]
11948	28	0	44	2	27
8482	9	14	51	4	22
11946	6	0	65	2	26
11752	0	0	38	0	62
11952	20	0	47	2	31

BASGO – ‘LHAKHANG CLOSE TO THE ROAD’. SAMPLE 8475

Sampling point

Ladakh, Basgo, ruin of a temple, is located along the left side of the road to Leh, and located at app. 34°12'45.09"N, 77°17'41.99"E. The names of the afore-treated temples, mentioned as Maitreya Lhakhang and Lotsāba Lhakhang, follow a locally common designation. In the case of this temple (which is related to sample 8475) no such obvious designation is available. For further treatment of this temple within this contribution, its location along the National Highway NH1D towards Leh is used as further designation and we simply refer to it as ‘Lhakhang close to the road’. The sample shows remains of the interior plaster. The thickness of the plaster is app. 2.5 cm. Sample number in the field: 37 BA-RZ/IP. Additives: Very long fibres of straw of up to 6 cm are present partially in a high amount. Constructive use: Interior wall plaster (Figs. 3.14 to 3.17).

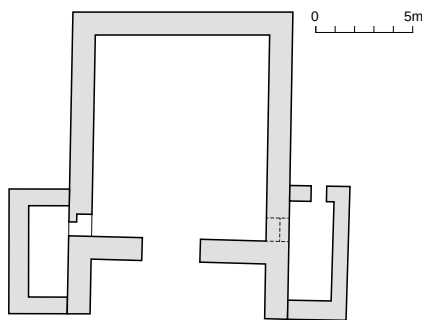


Fig. 3.14 (Top, left) Basgo. Lhakhang. Ground plan.

Fig. 3.15 (Top, right) Basgo. Lhakhang. View from the entrance towards the rear wall.

Fig. 3.16 (Bottom, left) Basgo. Lhakhang. Interior plaster (B/W).

Fig. 3.17 (Bottom, right) Basgo. Lhakhang. Exterior plaster.

Grain size distribution

The material is relatively fine, with the biggest fraction being fine gravel, which equals an amount relatively high for plaster. The median is located at app. 20 μm ; the $<2 \mu\text{m}$ fraction contains app. 18% of the whole sample. Together with the content of fine gravel, this amount may be relevant for the compensation of the high content of swellable clay to avoid cracks. The distribution curve shows a bimodal distribution with peaks of fine sand and fine silt – a possible evidence of a mixture with another clay or sand.

	Gravel	Sand	Silt	Clay [%]
8475 (plaster)	6.5	33.1	42.6	17.8

Grain shapes

Grain shapes between 200 μm and 6,300 μm are dominantly ‘angular-shaped’ without any evidence of a change in shape. This fact may indicate that the material is raw and unmixed.

Bulk mineral analysis

The sample contains a small amount of mica, amphiboles, 7Å minerals, quartz and K-feldspar. Plagioclase and calcite appear in a medium amount. Traces of 14Å minerals, phyllo silicates and hematite are available. The content of gypsum was measured at 2%, a possible indication for its use upon the plaster. A content of gypsum was also traced in the X-ray diffraction within a slower measurement. It is the only sample of the five examined samples of this temple with a conspicuous content of gypsum. Sample 11928 – also an interior plaster – only shows traces of gypsum. It is likely that the gypsum has already been washed out. The content of calcite of sample 8475 was measured at 13%. Compared to other Basgo samples, the content of calcite is evident in most of the samples, and an average amount of app. 8% to 10% seems to be naturally given. The colours are within the investigated range of Basgo samples. Due to traces of hematite, the sample is slightly red coloured.

Results measured with STA

- A peak at 128°C points towards the presence of gypsum.
- The residual mass at 1,000°C is 88.98%.

Clay mineral analysis

The CMA shows a scattered content of clay minerals with a relatively high content of illite and a high content of swellable clay minerals (33% of the clay fraction). The clay contains smectite and vermiculite. This sample shows similarity to the Basgo samples in general.

	Smectite	Verm18°	Illite	Kaolinite	Chlorite [%]
8475	24	9	43	3	21

BASGO – ‘LHAKHANG CLOSE TO THE ROAD’. SAMLPE 11928

Sampling point

Ladakh, Basgo, ruin of a temple along the left hand side of the road to Leh. Like sample 8475, it is located at app. 34°12'45.09"N, 77°17'41.99"E. Remains of the interior plaster. The thickness of the plaster is app. 2.5 cm. Sample number in the field: 47. Additives: Very long fibres of straw of up to 6 cm are partially present in a high amount. Constructive use: Interior wall plaster, similar to sample 8475 but from a different location within the wall.

Grain size distribution

The material is relatively fine; biggest fraction: fine gravel. The amount of gravel is relatively high for a plaster. The median is located at app. 15 µm; the <2 µm fraction contains app. 21% of the whole sample. The content of silt and sand together at 71.4% is relatively high and, together with the content of fine gravel, may be relevant for the compensation of the high content of swellable clay to avoid cracks. The peaks correspond to fine sand and fine silt – all data are relatively similar to sample 8475. Even the grain size distribution remains similar. The grain size distribution graphics shows a bimodal distribution – a possible evidence for the mixture with another material, similar to sample 8475.

	Gravel	Sand	Silt	Clay [values given in %]
11928 (plaster)	7.3	29.7	42.1	20.9
8475 (plaster)	6.5	33.1	42.6	17.8

Grain shapes

Grain shapes between 200 µm and 6,300 µm are dominantly angular-shaped without evidence of a change in shape. This fact may indicate the material as raw and unmixed.

Bulk mineral analysis

The sample contains a small amount of amphiboles, 7Å minerals, quartz, and K-feldspar (marked in Table 3 with *); dolomite at 2% and calcite at 12% is also indicated. 14Å minerals, mica, phyllosilicates, gypsum and hematite appear as traces. The amount of 12% of calcite follows an average quantity within the Basgo samples. The colours are within the investigated range of Basgo samples. Due to traces of hematite, the sample is slightly red coloured.

Clay mineral analysis

The CMA shows a scattered content of clay minerals with a relatively high content of illite and a slightly smaller content of swellable clay minerals in comparison to sample 8475. In this case the clay contains only smectite, and no vermiculite. It clearly shows similarity to the Basgo samples in general.

	Smectite	Verm18°	Illite	Kaolinite	Chlorite [%]
11928	18	0	41	5	37
8475	24	9	43	3	21

BASGO – ‘LHAKHANG CLOSE TO THE ROAD’. SAMPLE 8499

Sampling point

Ladakh, Basgo, ruin of a temple located along the left hand side of the road to Leh. Like sample 8475, it is located at app. 34°12'45.09"N, 77°17'41.99"E. Remains of the exterior plaster. The thickness of the plaster is app. 4 cm. Sample number in the field: 33 BA-RZ/AP. Additives: Fibres of straw of up to app. 3 cm are present in a high amount. Constructive use: Exterior wall plaster.

Grain size distribution

The material is coarser than interior plasters 8475 and 11928; biggest fraction: fine gravel. The median is located at app. 50 µm; the <2 µm fraction contains app. 12% of the whole sample. The content of sand at app. 39.6% and gravel at 7.5% shows a high amount of coarse material. For the exterior plaster, a higher content of coarse material makes the plaster more resistant to precipitation. As a comparison, in Austria a thick layer of clay plaster (“fir-coat”), locally also known as “Au-glehnert”, is known to be mixed with cow dung. Whether or not this was the case at early Himalayan temples cannot be stated within this study. Since in the Himalayas dung is traditionally known as an additive for earth constructions, we cannot exclude a particular use for plasters. In this sample the content of binding material seems to have been reduced to a small but still binding amount. The grain sizes show a wide range in their distribution. The amount of clay in sample 8499 (exterior plaster) is much smaller than for interior plaster samples 8475 and 11928.

	Gravel	Sand	Silt	Clay [%]
8499 (ext.plaster)	7.5	39.6	41.3	11.6
8475 (int. plaster)	6.5	33.1	42.6	17.8
11928 (int.plaster)	7.3	29.7	42.1	20.9

Grain shapes

Grain shapes between 200 µm and 6,300 µm are dominantly ‘angular-shaped’ without any evidence of a change of shape. This fact may indicate the material as raw and unmixed.

Bulk mineral analysis

The sample contains a small amount of mica, amphiboles, 7Å minerals, quartz and K-feldspar (in Table 3 marked with *); plagioclase appears in a medium amount (in the table marked with **). 14Å minerals, phyllo silicates and hematite appear as traces. Calcite is available at 15% and dolomite at 3%. The relatively high amount of calcite fits into the range of samples of this temple with a content between 12% and 15%. No traces of gypsum are present. It is similar to sample 8499. The colours are within the investigated range of Basgo samples. Due to traces of hematite the sample is slightly red coloured.

Clay mineral analysis

The CMA shows a scattered content of clay minerals with a relatively high content of swellable clay minerals. Smectite and vermiculite together make up 51% (of the clay fraction). Together with the content of fine gravel, the high amount of coarse material may be relevant for the compensation of the high content of swellable clay to avoid cracks. The following list shows a comparison with samples 8475 and 11928, with both coming from the same building and both showing

similarities to sample 8499. The CMA of sample 8499 (exterior plaster) shows slight similarities to sample 8483 (interior plaster in the Basgo Lotsāba Lhakhang) regarding a high content of swellable minerals (35% of the clay fraction) and the proportion of smectite and vermiculite. The amount of smectite is clearly higher in sample 8499. In sample 8483, a mixed layer shows a marker for its clearer local assignment.

	Smectite	Verm18°	Illite	Kaolinite	Chlorite [%]
8499	30	21	29	3	16
8475	24	9	43	3	21
11928	18	0	41	5	37
8483	20	15	44	3	22

BASGO – ‘LHAKHANG CLOSE TO THE ROAD’. SAMPLE 8472

Sampling point

Ladakh, Basgo, ruin of a temple located along the left hand side of the road to Leh. Same as sample 8475, it is located at app. 34°12'45.09"N, 77°17'41.99"E. Remains of an adobe brick. Sample number in the field: 32 BA-RZ/LS. Constructive use: Adobe brick.

Grain size distribution

The material is relatively coarse, with the biggest fraction being coarse and medium gravel (in the graphics, the total amount of gravel is shown in the FG (fine gravel fraction). The median is located at app. 550 µm; the <2 µm fraction contains app. 8% of the whole sample. The content of gravel at 35.8% and of sand at 42.5%, in summary 78.3%, shows a dominance of coarse material. The high amount of coarse material indicates a different treatment of the adobe brick material compared to the plaster samples. In this sample the content of binding material seems to have been reduced to a very small but still binding amount.

	Gravel	Sand	Silt	Clay [%]
8472 (adobe brick)	35.8	42.5	14.2	7.5
8475 (int. plaster)	6.5	33.1	42.6	17.8
8499 (ext.plaster)	7.5	39.6	41.3	11.6

Grain shapes

Grain shapes between 200 µm and 6,300 µm are dominantly ‘angular-shaped’ without any evidence of a change of shape. This fact indicates that the material is raw and unmixed.

Bulk mineral analysis

The sample contains a small amount of amphiboles, 7Å minerals, quartz and K-feldspar (marked in Table 3 with *); plagioclase and calcite appear in a medium amount (marked in the table with **). A content of gypsum was also found in trace amounts in the X-ray diffraction within a slower measurement. The content of calcite was measured at 12%, which compared to other Basgo samples is within an average amount. The colours are within the investigated range of Basgo samples. Since no hematite could be traced, the sample does not show any red colour.

Clay mineral analysis

The CMA shows a scattered content of clay minerals with a relatively high content of illite and a content of swellable clay minerals, in this case smectite and vermiculite. A relatively high content of these two minerals, together equally 23% (of the clay fraction), may explain a still available effect of binding despite a content of 35.8% gravel and 42.5% sand, together equalling 78.3% of coarse material. The result of the CMA fits well into basic features of most of the Basgo-Likir samples, i.e. a clear appearance of illite, up to a medium amount of smectite and vermiculite, a strong appearance of chlorite, and a few kaolinites. For the present sample, the amount of smectite is much less. This fits well for its use as material for the production of adobe bricks, since a minimal amount of smectite helps to avoid a high rate of deformation and cracks within the brick.

	Smectite	Verm18°	Illite	Kaolinite	Chlorite [%]
8472 (adobe brick)	9	14	50	4	23
8482 (int. plaster)	24	9	43	3	21
8499 (ext. plaster)	30	21	29	3	16

BASGO – LHAKHANG ‘CLOSE TO THE ROAD’. SAMPLE 11933

Sampling point

Ladakh, Basgo, ruin of a temple along the left hand side of the road to Leh. Same as sample 8475, it is located at app. 34°12'45.09"N, 77°17'41.99"E. Remains of an adobe brick. Sample number in the field: 45. Constructive use: Adobe brick.

Grain size distribution

The material is relatively coarse, with the biggest fraction being medium gravel (in the graphics the total amount of gravel is shown in the FG fraction). The median is located at app. 180 µm; the <2 µm fraction contains app. 10% of the whole sample. The content of gravel at 10.4% and of sand at 60.4%, together equalling 70.8%, shows a clear dominance of coarse material. The high amount of coarse material indicates different treatment of the adobe brick material. In this sample the content of binding material seems to have been reduced to a very small but still binding amount.

- a. Since with the CMA a strong similarity to sample 11946 (plaster in the Lotsāba Lhakhang) is stated, the grain size distributions will be compared. Regarding the grain size distribution, the two samples show similarity in the clay fraction and partially in the gravel fractions, but the silt and illite fractions appear completely different. The adobe brick is much coarser than the plaster.
- b. Since with the CMA a strong similarity to sample 11928 (plaster in the ‘Lhakhang close to the road’) is stated, grain size distributions will be compared. Regarding grain size distribution, the adobe brick is much coarser than the plaster. As comparison with another adobe brick, the data of sample 8472 will be added.

	Gravel	Sand	Silt	Clay [%]
11933 (adobe brick)	10.4	60.4	18.8	10.4
11928 (int. plaster)	7.3	29.7	42.1	20.9
8472 (adobe brick)	35.8	42.5	14.2	7.5
11946 (int. plaster Lotsāba Lk.)	5.2	16.3	62.9	15.6

Grain shapes

Grain shapes between 200 μm and 6,300 μm are dominantly ‘angular-shaped with a beginning rounding’ (Fig. 3.18). This fact may indicate the material as raw and unmixed.



Fig. 3.18 Shapes of grains in sample 11933. Scaled in millimetre.
Shape of fraction $>2,000 \mu\text{m}$ (left), $>630 \mu\text{m}$ (centre), $>200 \mu\text{m}$ (right).

Bulk mineral analysis

The sample contains a small amount of amphiboles, 7Å minerals, quartz and K-feldspar (marked in Table 3 with **); plagioclase appears in a medium amount (marked in the table with **). The amount of calcite was measured at 13% within the average range of Basgo samples. Dolomite, 14Å minerals, mica and phyllo silicates are all available in trace amounts. No gypsum could be detected. The colours are within the investigated range of Basgo samples. Since no hematite was identified, the sample does not show any red colour. The adobe brick was produced without any additives, similar to sample 8472.

a. A comparison of the BMA of sample 11933 with sample 11946 (plaster in the Lotsāba Lhakhang) shows great similarity between these two samples, contrary to differences in the grain size fractions.

b. A comparison of the BMA of sample 11933 with sample 11928 (plaster in the ‘Lhakhang close to the road’) also shows great similarity between these two samples, contrary to differences in the grain size fractions.

Clay mineral analysis

The CMA shows a scattered content of clay minerals with a relatively high content of illite and a small content of swellable clay minerals (in this case of smectite). The amount of kaolinite at app. 7% is relatively high compared to the other samples from this temple. The strong variation in the content of clay minerals between sample 8472 and 11933 indicates that they did not originate from the same clay pit. For comparison, sample 11946 (plaster from the Lotsāba Lhakhang) is listed below and shows close similarities to sample 11933. A close relation between samples

11933 and 11928 (respectively brick and plaster) points towards the possibility of the use of a particular basic material. The other samples (see the following listed samples) from this building (i.e. samples 8482, 8499 and 8472) show clear differences in comparison to sample 11933.

	Smectite	Verm18°	Illite	Kaolinite	Chlorite [%]
11933 (adobe brick)	9	0	53	7	32
11928 (int. plaster)	24	9	43	3	21
8472 (adobe brick)	9	14	50	4	23
11946 (int. plaster Lotsāba)	6	0	65	2	26

BASGO – BUILDING RAW MATERIAL. SAMPLE 15410

Sampling point

Ladakh, Basgo. Red coloured clay from north of the Maitreya Lhakhang (upper temple) (Fig. 3.19), located at app. 34°13'28.78"N, 77°16'38.23"E. The local terminology is *dzasa* (Tib. *rdza sa*), which possibly derives from pottery clay. An area, which is located about 2 km north of the temple hill, is called “*zasna*” (pronounced) and points towards the influence of local clay on toponymies. This material is one of the basic types of clay for building purposes in the area around the monastery hill. Along with the sandy *thetsa* (Tib. *'phred sa*), it is used as part of a mixture for the preparation of plasters. As mentioned by locals, this plaster is applied in two layers. The lower (levelling) layer is mixed with straw. For the upper (fine) layer, the same mixture is used without straw. Such a two-layer plaster is found throughout this region with changing thickness and a variable amount of straw. Sample number in the field: 74 BA/LG.



Fig. 3.19 Basgo. Sample 15410.
Sample colour (after Munsell):
Dry 10YR 6/2 light brownish grey.
Semi-dry 10YR 4/2 dark
greyish brown.

Grain size distribution

The material is coarse, with the biggest fraction being medium and fine gravel. The median is located at app. 2,000 μm ; the $<2 \mu\text{m}$ fraction contains app. 8% of the whole sample. The gravel fractions together equal about 53.9% of the whole sample. The maximum peak is 41.2%, with medium gravel dominating the whole sample. The distribution curve shows a bimodal distribution with a deep valley between fine gravel and fine sand. Due to this valley the fractions of fine

sand and smaller parts are easily separated from the whole sample, and the finer portion of material can be used for another purpose. This silt-dominated portion of the sample, which includes some clay, is appropriate for the mixing of plaster with coarse material such as *thetsa*. Instead of desludging, the gravel fraction and the fine material can be separated from each other by sieving. Nevertheless, due to the gravel-fraction, the coarse content must be separated to achieve a material much finer than shown by samples of *thetsa* (described with samples 11915 and 15411). Perhaps pits exist with only the fine content and without the content of gravel. Another hypothesis can be that the rather high content of gravel shows a relatively high amount of coarse material in laboratory research, but the haptic impression in the field differs due to a high content of silt. This may also be the reason why locally it is known as a fine material. Apart from the high amount of gravel, the grain size distribution shows a well-sorted curve. On the other hand, we may not exclude the possibility that coarse material was added to a fine and silt dominated *dzasa* sample.

	Gravel	Sand	Silt	Clay [%]
15410 <i>dzasa</i>	53.9	8.7	30.7	6.9

Bulk mineral analysis

The sample contains a small amount of 7Å minerals, quartz and plagioclase (marked in the table with *). Traces of 14Å minerals, mica, amphiboles, phyllo silicates, K-feldspar and dolomite (1%) appear as traces without indications of a content of gypsum. At 10%, the amount of calcite is average.

Clay mineral analysis

Similar to samples 15411 and 11915, this sample shows a high content of the swellable mineral smectite (see Fig. CMA 3.28 in the Appendix of Chapter III).

	Smectite	Verm18°	Illite	Kaolinite	Chlorite [%]
15410 (<i>dzasa</i>)	30	0	32	2	36

BASGO – BUILDING RAW MATERIAL. SAMPLE 11915

Sampling point

Ladakh, Basgo, like sample 15410, is located at app. 34°13'28.78"N, 77°16'38.23"E. The local terminology is *thetsa* (Tib. *'phred sa*), also known as “*thetsa sand*”, which already points towards its use as an additive locally mixed with the *dzasa* (Tib. *rdza sa*) (Fig. 3.20). Sample number in the field: 20. Constructive use: Raw material for the sandy additive for the preparation of a plaster.

Grain size distribution

The material is coarse, with the biggest fraction being fine gravel. The median is located at app. 250 µm; the <2 µm fraction contains app. 9% of the whole sample. The gravel and sand fractions amount to about 77.9% of the whole material. The maximum peak is 41.1% of medium sand. Sand dominates the whole sample. This sample shows no bimodal distribution. This may be a hint that this material was not separated from another sample but used as a homogenous material with sandy dominance – contrary to the *dzasa*, which was separated and of which the finer fractions were probably preferred for the preparation of plasters. The high content of sand is clearly visible.



Fig. 3.20 Basgo. Sample 11915.
Sample colour (after Munsell):
Dry 10YR (6)7/1 light grey.
Semi-dry 10YR 4/1 dark grey.

Gravel	Sand	Silt	Clay [%]		
11915 (<i>thetsa</i>)		3.8	74.1	14	8.2
15410 (<i>dzasa</i>)		53.9	8.7	30.7	6.9

Bulk mineral analysis

The BMA shows clear differences to the *dzasa* (15410): The sample contains only traces of 7Å minerals. It also contains a small amount of quartz but a higher amount of plagioclase. Compared to sample 15410, no traces of dolomite are present, and further no traces of 14Å minerals or amphiboles are present. The K-feldspar is available in a small amount, while for sample 15410 it appears only in lesser trace amounts. Small reddish spots point towards a content of hematite. The amount of calcite at 7% is below the average level (10%–11%) for the samples in this region. Since this sample is used as raw material for mixing, we can assume that an average content of calcite is stated as naturally given. The sample does not show any content of gypsum. It is relatively greyish and shows reddish spots, probably traces of hematite.

Clay mineral analysis

The CMA shows a scattered content of the clay minerals. Compared with sample 15410, the content of clay minerals is clearly different. The content of illite and chlorite is much less compared to sample 15410. Regarding the CMA, in particular the high amount of swellable minerals – 53% (of the clay fraction) for sample 11748 (used for making a clay stove) – shows similarities to sample 11915 – which contains 72% swellable material (i.e. a *thetsa*, which is not used for making a stove). Due to this analysis we can state that the *thetsa* potentially gives an optic and haptic impression of being coarse and thus may be known as a sandy material. Additionally, the content of clay minerals is similar to *dzasa* sample 15410, and furthermore the content of swellable minerals at 72% (of the clay fraction) is more than double compared to sample 15410 at 30%. This emphasises once more the hypothesis that sample 15410 shows an amount of gravel above average for *dzasa* raw material.

Regarding the rather high content of swellable clay minerals, this high amount we know from bentonites with a content of app. 60% to 80% of clay minerals, in this case montmorillonite, which belongs to the smectite group that is a 2:1-clay mineral classified by a layer charge of 0.25 to 0.6. Montmorillonites also show a content of mica and chlorite. At this point, the question for a volcanic indicator arises. The 2 µm CMA-graphics shows a di-octahedric smectite at app. 62°. Since the quartz peak at app. 60° is higher than the one at app. 50°, the additional share may be described as content of mica. The sample may speculatively be described as a volcanic ash of old age. With a content of app. 80% of framework material and 20% of binding material, this material can be described as a building material with a high binding effect in spite of its rather coarse appearance.

	Smectite	Verm18°	Illite	Kaolinite	Chlorite [%]
11915 (<i>thetsa</i>)	72 (smec + verm)		13	6	8
15410 (<i>dzasa</i>)	30	0	32	2	36
11748 (<i>thab</i>)	11	42	10	37	0

BASGO – BUILDING RAW MATERIAL. SAMPLE 15411

Sampling point

Ladakh, Basgo, similar to sample 15410, is located at app. 34°13'28.78"N, 77°16'38.23"E. The local terminology is *thetsa* (Tib. *'phred sa*) (Fig. 3.21). This is another sample of this material for further comparison. As mentioned before, this material is known for the preparation of a plaster but it is also recognised for the preparation of flat roofs and floors, in particular for the lower (first) layer, which can also be mixed with very coarse material with a size of up to 1 cm to 2 cm. The uppermost layer used for flat roofs was mentioned either as *markalak* (Feiglstorfer 2019: 199ff.) or as *khusa* (Feiglstorfer 2014: 378), which is a kind of sooty material (mostly a recycled plaster from kitchens)⁹⁰. For the preparation of adobe bricks, this kind of *thetsa* is used without any further mineral addition. If needed, straw can be added. Sample number in the field: 75 BA/LG. Constructive use: Raw material for the sandy additive for the preparation of a plaster. It is also used for the lower layer of flat roofs and the preparation of adobe bricks without any further mineral addition.

Grain size distribution

The material is coarse and as expected similar to the *thetsa* sample 11915; biggest fraction: fine gravel. The median is located at app. 240 µm versus 250 µm for sample 11915; the <2 µm fraction contains app. 9% of the whole sample, same as for sample 11915. The gravel and sand fractions amount to about 74.8% of the whole material versus 67.9% for sample 11915. The maximum peak is 32.7% medium sand. Sand dominates the whole sample. There is no bimodal distribution as in sample 15410. This may indicate that the material was not separated but rather used as a homogenous material with sandy dominance. This is contrary to the *dzasa*, which may have been separated and of which finer fractions were preferred for the preparation of plaster. The sample is obviously sandy.

90 Interview with Sonam Dawa in Leh, August 2002: When using 'high-quality' clay for the top roof layer and eventually adding ash, daily clearing of the snow from the roof is not required.



Fig. 3.21 Basgo. Sample 15411.
Sample colour (after Munsell):
Dry 10YR 6/2 light brownish grey.
Semi-dry 10YR 4/2 dark greyish brown.

	Gravel	Sand	Silt	Clay [%]
15411 (<i>thetsa</i>)	6.0	68.8	16.5	8.7
15410 (<i>dzasa</i>)	53.9	8.7	30.7	6.9
11915 (<i>thetsa</i>)	3.8	74.1	14	8.2

Bulk mineral analysis

With slight differences, the BMA shows close similarities to sample 11915: The differences are the content of 7Å minerals in small amounts as opposed to trace amounts, and amphiboles and 14Å minerals as traces. In sample 11915 amphiboles and 14Å minerals are missing; a higher content of K-feldspar appears in a medium amount (marked in Table 3 with **), contrary to sample 11915, which shows only a small amount. The content of calcite in sample 15411 is 11% compared to 7% in sample 11915. Similarly, no dolomite and gypsum were traced. The content of calcite was measured at 11%.

Clay mineral analysis

The CMA shows a scattered content of clay minerals. A comparison with *thetsa* sample 11915 shows similarities but also differences. These differences emphasise the fact that two materials with the same local name and a high similarity in their grain size distribution and in their bulk mineral consistency must not necessarily follow a similarity of clay mineral content. Simply having clay from a different clay pit may change the clay mineralogical composition and by that also its particular behaviour as a building material. In this particular context, the 38% content of smectite as a swellable material in sample 15411 compared with 72% of smectite and vermiculite in sample 11915 must result in a different behaviour regarding swellability. The high content of chlorite indicates the metamorphic character of this material differing from smectite and mica, possibly due to a different means of geological material transport.

Both *thetsa* samples (11915 and 15411) are relatively similar regarding the BMA but show differences when comparing their CMA, as shown in the following juxtaposition.

	Smectite	Verm18°	Illite	Kaolinite	Chlorite [%]
15411 (<i>thetsa</i>)	38 (smec + verm)		26	0	36
15410 (<i>dzasa</i>)	30	0	32	2	36
11915 (<i>thetsa</i>)	72 (smec + verm)		13	6	8

BASGO – BUILDING RAW MATERIAL. SAMPLE 8465

Sampling point

Ladakh, Basgo, a clay pit located beside the Maitreya Lhakhang at 34°13'27.07"N, 77°16'36.70"E. This material is mixed and ready for application on a roof (Fig. 3.22). In a further step, this material is mixed with straw. General local information designated this material as a high-quality building material. The two afore-mentioned types of clay, *thetsa* and *dzasa*, are mixed. On wooden stretchers the final mixtures were carried along steps onto the roof and sectionally poured onto the afore-applied layer of *jaksas* (Figs. 3.23, 3.34). After a short drying process the applied and still humid sediment was compressed and flattened with wooden beaters. These beaters had a similar form to what is known from the construction of the *arga* roof (cf. Feiglstorfer 2019).

Sample number in the field: 31 BA/LG. Additives: Pieces of wood and long pieces of straw. Constructive use: Mixture of *thetsa*, *dzasa* and straw for flat roof construction.



Fig. 3.22 Basgo. Sample 8465.
Sample colour (after Munsell):
Dry 10YR 7/2 light grey.
Semi-dry 10YR 5/3 brown.



Fig. 3.23 (Left) Basgo. Maitreya Lhakhang. New roof construction.

Fig. 3.24 (Right) Basgo. Maitreya Lhakhang. One layer of a mixture of *thetsa* and *dzasa*.

Grain size distribution

The material is coarse and shows similar qualities to a mixture of the *thetsa* and *dzasa* samples; biggest fraction: fine gravel. The median is located at app. 210 μm versus 240 μm for sample 15411, and 2,000 μm for sample 15410; the $<2\ \mu\text{m}$ fraction contains app. 11% for the whole sample, compared to 9% for sample 15411, and 8% for sample 15410. The gravel and sand fractions amount to about 63.3 % versus 74.8% of the whole material for sample 15411, and 62.6% for sample 15410. The maximum peak is 24.5% medium sand. The coarse fractions of sand and gravel dominate the sample.

	Gravel	Sand	Silt	Clay [%]
8465 (<i>dzasa+thetsa</i>)	12.5	50.8	25.8	10.9
15410 (<i>dzasa</i>)	53.9	8.7	30.7	6.9
15411 (<i>thetsa</i>)	6.0	68.8	16.5	8.7

Grain shapes

The size of the grains is up to 14 mm. The $>2,000\ \mu\text{m}$ fractions are ‘slightly rounded shaped’ and also ‘angular-shaped’, while the fractions below are dominantly ‘angular-shaped’. The change in the shape at around 2,000 μm may be an indication of the addition of a coarse material (Fig. 3.25). Regarding the two different grain shapes, the grain size distribution points to the use of two different kinds of raw material and not being a natural mixture.

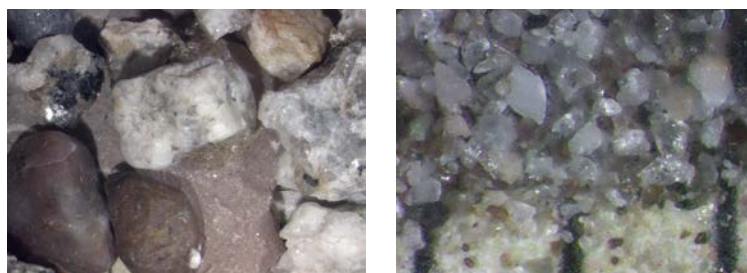


Fig. 3.25 Shapes of grains in sample 8465. Scaled in millimetre.
Shape of fraction $>2,000\ \mu\text{m}$ (left), $>200\ \mu\text{m}$ (right).

Bulk mineral analysis

The BMA clearly shows properties of both types of clay: *thetsa* and *dzasa*. 14Å minerals, hematite and mica occur as traces, while amphiboles, 7Å minerals, phyllo silicates and quartz appear in a small amount (marked in Table 3 with *). K-feldspar and plagioclase are present in a medium and relatively high amount, respectively. Calcite ranges from 10% to 11%, with 10% being the average level. Traces of gypsum are present.

Results measured with STA

- A peak at 117°C points towards the presence of gypsum.
- The residual mass at 1,000°C is 92.03%.

Clay mineral analysis

The CMA shows a scattered content of clay minerals. A comparison with *thetsa* sample 15411 and *dzasa* sample 15410 regarding swellable clay minerals provides the following results: 29% for sample 8465, slightly above 30% for sample 15410, and 24% for sample 15411. The content

of kaolinite is comparably low, while the value for illite is with 51% above the values of samples 15410, 11915 and 15411.

	Smectite	Verm18°	Illite	Kaolinite	Chlorite [%]
8465 (<i>dzasa+thetsa</i>)	18	11	51	4	16
15410 (<i>dzasa</i>)	30	0	32	2	36
15411 (<i>thetsa</i>)	38 (smec + verm)		26	0	36

BASGO – BUILDING RAW MATERIAL. SAMPLE 11952

Sampling point

Ladakh, Basgo, new adobe brick. The material was found along a building site beside the *chorten* close to the Lotsāba Lhakhang, located at app. 34°13'26.12"N, 77°16'31.26"E. The brick is a recent production (Fig. 3.26). Sample number in the field: 70. Additives: Short pieces of straw and pieces (up to app. 5 cm) of small branches were detected. For the preparation of adobe bricks in this area, straw was perhaps added due to the high content of clay and swellable clay minerals. Constructive use: Adobe brick.



Fig. 3.26 Basgo. Sample 11952. Sample colour (after Munsell): Dry 10YR 6/2 light brownish grey. Semi-dry 10YR 3/2 very dark greyish brown.

Grain size distribution

The material is obviously a mixture of coarse and fine material. The intention of the producers must have been a wide range of fractions but does not follow the kind of flat roof mixture of the *thetsa* and *dzasa* (which we observed with sample 8465). The distribution of fine and coarse is much more homogenous than found in flat roof sample 8465 or in plaster sample 15410. Biggest fraction: fine gravel. The median is located at app. 31 μm versus 210 μm for flat roof sample 8465; the <2 μm fraction contains app. 19% of the whole sample versus 11% for flat roof sample 8465. The content of clay and silt (together equalling 58%) is relatively high compared to the other samples within this group of building raw materials. Compared to bricks from the Maitreya Lhakhang and the Lotsāba Lhakhang, this mixture is particular with a clear difference in the choice of the raw materials. The following list compares sample 11952 with other samples of this group, and with sample 11948, i.e. the brick sample from the Lotsāba Lhakhang.

	Gravel	Sand	Silt	Clay [%]
11952 (adobe brick)	6.7	35.3	38.7	19.3
15410 (<i>dzasa</i>)	53.9	8.7	30.7	6.9
8465 (<i>dzasa+thetsa</i>)	12.5	50.8	25.8	10.9
11948 (adobe brick Lotsāba Lk.)	17.2	51.0	21.8	10.0

Grain shapes

The size of the grains is up to 17 mm. The $>6,300\ \mu\text{m}$ and $>2,000\ \mu\text{m}$ fractions are ‘slightly round-ed-shaped’ and also ‘angular-shaped’, while the fractions below are dominantly ‘angular-shaped’. This change in the shape at around $2,000\ \mu\text{m}$ may be an indication for the addition of coarse material (Fig. 3.27). Regarding the grain shapes, the grain size distribution points to the use of two different kinds of raw material and not a natural mixture. According to the grain shapes, the grain size distribution points to the use of two different kinds of raw material.



Fig. 3.27 Shapes of grains in sample 11952. Scaled in millimetre.
Shape of fraction $>2,000\ \mu\text{m}$ (left), $>630\ \mu\text{m}$ (centre), $>200\ \mu\text{m}$ (right).

Bulk mineral analysis

The BMA clearly shows properties close to those of this group of raw materials. $14\text{\AA}$ minerals, mica, hematite and amphiboles occur as traces, while dolomite (app. 1%), $7\text{\AA}$ minerals, phyllosilicates, quartz, K-feldspar and plagioclase occur in small amounts (marked in Table 3 with *). The content of calcite was measured at 11%, and no gypsum was traced.

Clay mineral analysis

The CMA shows a scattered content of the clay minerals. In comparison with the other samples of this group of building materials, sample 11952 shows the lowest content of swellable clay minerals. On the other hand, a relatively high content of silt is present. This lower content of swellable minerals may explain why this sample, which has such a high content of clay minerals, does not shrink much or crack. The content of sand and gravel (together 42%) supports this behaviour, which is the aim for adobe brick material.

	Smectite	Verm18°	Illite	Kaolinite	Chlorite [%]
11952 (adobe brick)	20	0	47	2	31
15410 (<i>dzasa</i>)	30	0	32	2	36
15411 (<i>thetsa</i>)	38 (smec + verm)		26	0	36
8465 (<i>dzasa+thetsa</i>)	18	11	51	4	16

BASGO – CLAY STOVE (TIB. *thab*). SAMPLE 11748

Sampling point

Ladakh, Tunlung near Basgo. The pit is located along the slope of a hill at app. 34°14'9.79"N, 77°16'50.22"E. Small digging holes indicate that this place has been known for the collection of raw material (Fig. 3.28). It is said that the proper material can be crumbled between the fingers of one hand. Furthermore, a dark colour indicates higher humidity and by that easier crumbling. At first glance the collected samples seemed to be a kind of stone material. After several attempts, the material crumbled between the fingers into small sandy pieces, giving the impression that it did not contain enough binding material. The right proportion of water is required to reach the state of 'norm stiffness' (Ger. *Normsteife*) so that the raw material becomes smoother, and capable of binding and processing. Sample number in the field: 5. Constructive use: Clay for the production of a clay stove (Figs. 3.29 to 3.34).



Fig. 3.28 Tunlung. Sample 11748.
Sample colour (after Munsell):
Dry10YR 7/6 yellow.
Semi-dry 10YR 5/6 yellowish brown.

Grain size distribution

The material is relatively coarse, with the biggest fraction being coarse and medium gravel. In the grain size graphics, fine and coarse gravel are displayed together in the FG peak. The median is located at app. 650 µm; the <2 µm fraction contains app. 9% of the whole sample. The content of gravel is 31.8% and the content of sand 44.7%. Together at 76.5%, this sample shows a relatively high content of coarse material. This may be relevant for the compensation of the high content of swellable clay to avoid cracks and also for reduced elongation during heating. The maximum peak corresponds clearly to the gravel fraction. The grain size distribution graphics do not show an immediate break or bimodal distribution. Since the material was taken from the pit, the addition of material to this sample can be excluded.

	Gravel	Sand	Silt	Clay [%]
11748	31.8	44.7	15.6	7.9 (raw material)

Grain shapes

The grain shapes between 200 µm and 6,300 µm are dominantly 'angular-shaped' and continuously display the same rounding, thus giving no evidence of mixing.

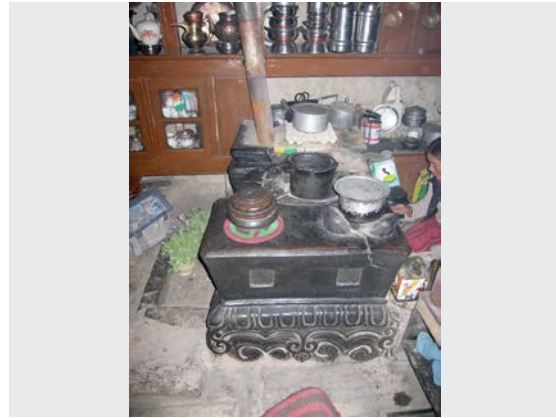


Fig. 3.29 (Top, left) Ladakh. Basgo. In a Tibetan farmhouse, a *thab* is a social centre of daily life.

Fig. 3.30 (Top, right) Ladakh. Basgo. A *thab* still in use.

Fig. 3.31 (Centre, left) Ladakh. Basgo. Serzang Lhakhang. Broken *thab*.

Fig. 3.32 (Centre, right) Ladakh. Basgo. Serzang Lhakhang. Broken *thab*.

Fig. 3.33 (Bottom, left) Ladakh. Taktok. Former monastery kitchen in a cave with a broken *thab*.

Fig. 3.34 (Bottom, right) Ladakh. Taktok. Former monastery kitchen. Broken *thab*.

Bulk mineral analysis

The sample contains a small amount of 14Å minerals mica, phyllo silicates, quartz, K-feldspar, and plagioclase, and a higher amount of 7Å minerals. Goethite and hematite were found in trace amounts. The stove clay does not contain calcite. The lack of calcite also supports the material's use at higher temperatures, similar to *thabsa* samples 11748, 15412 and 11919. Contrarily, pottery clay samples 15515 and 11752, i.e. also for use at higher temperatures, contain calcite. No gypsum could be traced, contradicting use at high temperatures, similar to samples 15412 and 11919, which are also used for stove production. The colours are outside the investigated range of Basgo samples, since they are relatively yellowish, and in a dry and also a semi-dry state. The X-ray diffraction shows a clear peak at 17.8° (2θ).

Results measured with STA

- A peak at 301°C points towards the content of goethite.
- A peak at 537°C points towards a dehydroxilation of kaolinite.
- The residual mass at 1,000°C is 92.44%.

Clay mineral analysis

The CMA shows a scattered content of clay minerals with a relatively high content of kaolinite and swellable clay minerals (smectite and in particular vermiculite at 42% of the clay fraction). It generally does not show similarity to the Basgo samples, with an exception being the other *thabsa* samples. The high content of kaolinite is a factor for increasing resistance against the high temperature that occurs when firing a stove. Chlorite is missing. The high content of smectite and vermiculite in combination with kaolinite shows a technical conflict regarding heat resistance. While smectite and vermiculite enable swelling, kaolinite supports a form of stability. A content of well-crystalised kaolinite is found in this sample.

	Smectite	Verm18°	Illite	Kaolinite	Chlorite [%]
11748 (<i>thabsa</i>)	11	42	10	37	0

BASGO – CLAY STOVE (*thab*). SAMPLE 15412

Sampling point

Ladakh, Tunlung near Basgo. The pit is located along the slope of a hill at app. 34°14'9.79"N, 77°16'50.22"E (Fig. 3.35). Small digging holes along the road indicate that this place has been known as a location for collecting raw material. The material is similar to sample 11748, which was taken about one metre to the side. Sample number in the field: 76 BA/LG. Constructive use: Clay for the production of an oven. Its use for roofs is problematic, since it becomes a clayey mass when getting in contact with water, although it is mentioned as a material for making floors (Feiglstorfer 2014: 372).



Fig. 3.35 Tunlung. Sample 15412.
Sample colour (after Munsell):
Dry 10YR 7/6 yellow.
Semi-dry 10YR 5/6 yellowish brown.

Grain size distribution

The material is relatively coarse, with the biggest fraction being medium and fine gravel. The median is located at app. 180 μm , much lower than for sample 11748; the $<2 \mu\text{m}$ fraction contains app. 14% of the whole sample. In general this material has a higher content of fine material than sample 11748. The content of gravel is 23.7%, and the content of sand 39.6%. In combination giving 63.3%, the material is relatively coarse. This may be relevant for the compensation of the high content of swellable clay to avoid cracks and also to reduce elongation during heating. The maximum peak corresponds to the gravel fraction. The grain size distribution graphics do not show an immediate break or bimodal distribution. Since the material was taken directly from the pit, the addition of material in this sample can be excluded.

	Gravel	Sand	Silt	Clay [%]
15412 (<i>thabsa</i>)	23.7%	39.5%	22.8%	13.9% (raw material)
11748 (<i>thabsa</i>)	31.8%	44.7%	15.6%	7.9% (raw material)

Bulk mineral analysis

The sample, which is very similar to sample 11748, contains a small amount of 14Å minerals, mica, 7Å minerals, phyllo silicates, quartz, plagioclase and K-feldspar, and no calcite or gypsum. The colours are outside the investigated range of Basgo samples, since they are relatively yellowish in a dry and also semi-dry state. The BMA shows a clear peak of 17.8° (2 θ) and the STA shows a peak of 302°C. The content of a goethite could be proven.

Results measured with STA (Fig. 3.36)

- A peak at 302°C points towards the content of goethite.
- A peak at 526°C points towards a dehydroxilation of kaolinite.
- The residual mass at 1,000°C is 93.3%.

Clay mineral analysis

The CMA shows a scattered content of clay minerals with a relatively high content of kaolinite and swellable clay minerals, i.e. smectite and in particular vermiculite at 42%. It does not show similarity to the Basgo samples in general. In the stove clay samples, chlorite is missing. The CMA of this sample along with the content of swellable clay minerals is similar to sample 15412.

Kaolinite could be identified as well-crystallised in the CMA and the IRS. Moreover, with the IRS analysis, several other minerals, such as smectite and quartz, were proven (see Fig. IRS 3.1 in the Appendix of Chapter III).

	Smectite	Verm18°	Illite	Kaolinite	Chlorite [%]
15412 (<i>thabsa</i>)	20	28	19	33	0
11748 (<i>thabsa</i>)	11	42	10	37	0

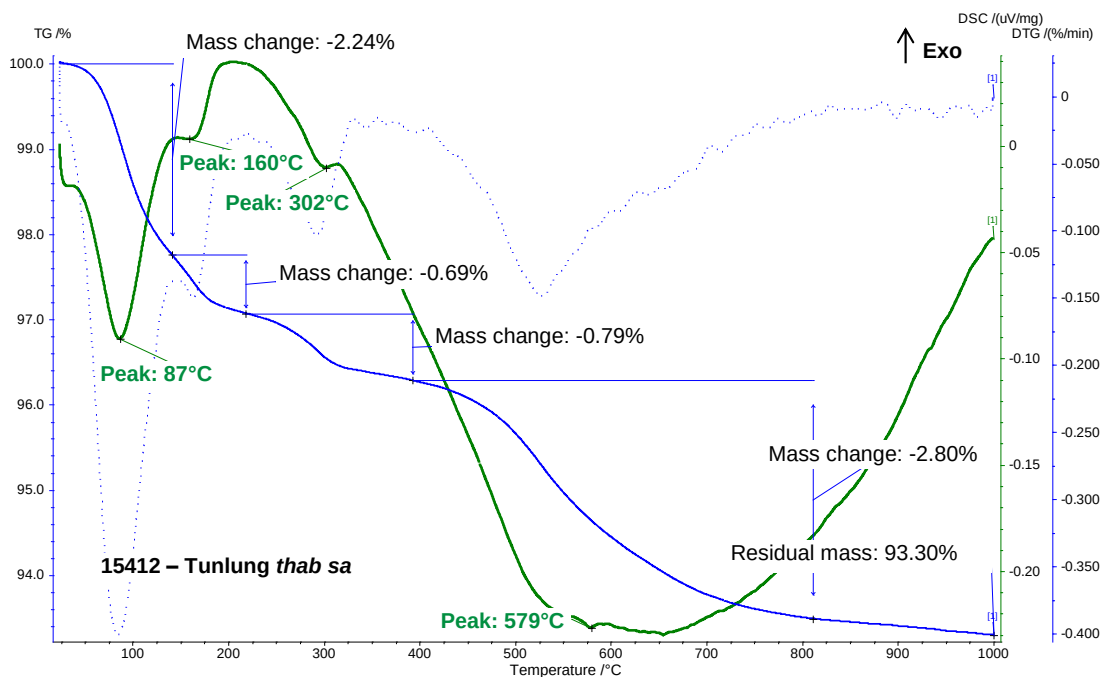


Fig. 3.36 Tunlung. Sample 15412. STA showing a content of goethite.

BASGO – CLAY STOVE. SAMPLE 11919

Sampling point

Ladakh, Ne (34°16'39.44"N, 77°17'57.91"E) located about 7 km north of Basgo. The material was collected at the foot of the 'temple hill' opposite the village of Ne (Fig. 3.37). Tsewang Norbu, a stove maker from Ne, collected the material and spoke of it as a better processable material than the material collected for samples 11748 and 15412. He also explained the procedure of making a stove from this material.⁹¹ Sample number in the field: 32. Constructive use: Clay stove.

Grain size distribution

The material is relatively coarse, with the biggest fraction being fine gravel. The median is located at app. 380 μm ; the <2 μm fraction contains app. 10% of the whole sample. The content of gravel is 21.2% and the content of sand is 44.1%, which together at 65.3% show a relatively high content

⁹¹ A detailed documentation of the method for preparation of a clay stove is given in Feiglstorfer 2014: 383–386.



Fig. 3.37 Tunlung. Sample 11919.
Sample colour (after Munsell):
Dry 10YR 8/1 white.
Semi-dry 10YR 8/2 very pale brown.

of coarse material. This may be relevant for the compensation of the high content of swellable clay to avoid cracks and also for reduced elongation during heating. The peak clearly corresponds to the gravel fraction. The grain size distribution graphics do not show an immediate break or a bimodal distribution. Since the material was taken directly from the pit, the addition of material in this sample can be excluded. Generally speaking, this material is much more similar to sample 11748 than it is to samples 11748 and 15412, although the latter two were collected close to one another and look very similar to each other. Grain shapes between the 200 μm and 6,300 μm fractions are dominantly ‘angular-shaped’, giving no evidence of a mixture.

	Gravel	Sand	Silt	Clay [%]	
11919 (Ne)	21.2	44.1	24.3	10.3	(raw material)
11748 (Tunlung)	31.8	44.7	15.6	7.9	(raw material)
15412 (Tunlung)	23.7	39.5	22.8	13.9	(raw material)

Bulk mineral analysis

The sample differs from samples 11748 and 15412 in that the mica is only available in trace amounts. Furthermore, the content of K-feldspar is much higher in sample 11919 (marked in Table 3 with ***). Compared to most of the other Basgo-Likir samples, but unlike stove samples 11748 and 15412, the stove clay contains traces of calcite, measured at 3%. Like stove samples 11748 and 15412, this sample does not contain gypsum. Besides proving the content of well-crystallised kaolinite, several other minerals such as smectite and quartz could be determined. The colours are outside the investigated range of Basgo samples and also differ from the two other stove samples in that they are much brighter. A slight content of hematite may be responsible for some reddish spots within the sample.

Results measured with STA

- A peak at 526°C points towards a dehydroxilation of kaolinite.
- The residual mass at 1,000°C is 95.1%.

Clay mineral analysis

The scattered content of clay minerals is similar to stove samples 11748 and 15412. At 57%, the content of swellable clay minerals is the highest compared to samples 11748 and 15412. The kaolinite could be identified as well-crystallised in the CMA, and was also recognised with the IRS (see Fig. IRS 3.2 in the Appendix Chapter III). It is significant to note that the content of chlorite in the oven material is also 0%.

	Smectite	Verm18°	Illite	Kaolinite	Chlorite [%]
11919 (Ne)	38	19	7	36	0
11748 (Tunlung)	11	42	10	37	0
15412 (Tunlung)	20	28	19	33	0

BASGO / LIKIR – STOVE AND POTTERY CLAY. SAMPLE 15515

Sampling point

Ladakh, Basgo, collected at two small caves of an app. size of 2 x 2 x 1 m (L/B/H). These caves are located at the foot of the temple hill with the monastery and palace on top, just beside Highway NH1D, on the left side when moving towards Leh. The surface of the cave walls was dark, shiny and showed traces of recent digging. Apparently this material (Fig. 3.38) is still collected for its special qualities. It can be dug in layers by breaking the layers by hand. Sample number in the field: 81 BA/LG. Constructive use: This clay is known as *thabsa*. After ramming and compressing, water is added. Thereafter it is said to have the characteristic of ‘stone’-like hardness. It is different to sample 15412 from Tunlung, which is also known for its use for making floors. According to the potters from Likir, this material is used for the production of *tandoor* stoves. It is simply made by covering the inside of metal barrels.



Fig. 3.38 Basgo. Sample 15515.
Sample colour (after Munsell):
Dry 10YR 8/1 white.
Semi-dry 10YR 8/2 very pale brown.

Grain size distribution

Compared with the *thabsa* (samples 11748, 15412, and 11919), the material is much finer with nearly no sand and gravel and a much higher content of silt and clay. The biggest fraction is medium sand (not including the 0.6% amount of only coarse sand). The median is located at app.

2.5 μm ; the $<2 \mu\text{m}$ fraction contains app. 42% of the whole sample. The content of gravel is 0.1% and the content of sand is 3.2%. Together equalling 3.3%, the sample shows a very small content of coarse material (fine gravel and sand) versus a very high content of fine material (silt and clay) at 96.7%. This may be relevant for the processing of the material with the aim to create a fine layer important for its later use in the construction of a stove. On the other hand, to avoid shrinkage, a relatively high content of silt (54.5%) is available. At 42.9%, the maximum peak clearly corresponds to the fine silt fraction. The grain size distribution graphics do not show an immediate break or bimodal distribution. Since the material was taken directly from the pit, an addition of material in this sample can be excluded.

	Gravel	Sand	Silt	Clay [%]
15515	0.1	3.2	54.5	42.2 (raw material)

Bulk mineral analysis

In general the sample shows similarities to the appearance of most of the samples in this region. There is no content of amphiboles and K-feldspar, and only traces of 14Å minerals. Mica, 7Å minerals, phyllo silicates, quartz and plagioclase occur in small amounts (marked in Table 3 with *) and dolomite makes up 2%. The content of calcite was measured at 4% (as shown in Table 3). This value is lower than the average content of calcite measured in this region. No gypsum could be traced. A content of hematite gives this sample a reddish appearance.

Clay mineral analysis

The CMA of this sample shows a less scattered content of clay minerals as observed in most other Basgo-Likir samples, and no swellable clay minerals (smectite or vermiculite) can be traced. This points towards the quality of remaining free of cracks when firing. The content of chlorite is the highest for the Basgo-Likir samples, and differs from *thabsa* samples 11748, 11919 and 15412 from Tunlung and Ne, which show no content of chlorite. On the other hand, kaolinite cannot be traced, which is different to the *thabsa* samples with a content of kaolinite between 12% and 57%. All three samples used for pottery or the interior panelling of *tandoor* stoves show a content of corrensite, which is a mixed layer mineral of chlorite and smectite, and a marker for these samples. At app. $3^\circ\theta$ the curve shows a small peak. This peak is a result of the widening (swelling) due to the swellable content, which shifted from the chlorite peak at app. $6^\circ\theta$ in a left direction.

	Smectite	Verm18°	Illite	Kaolinite	Chlorite [%]
15515 (Basgo cave)	0	0	31	0	69
11748 (Tunlung)	11	42	10	37	0
11919 (Ne)	38	19	7	36	0

BASGO / LIKIR – STOVE AND POTTERY CLAY. SAMPLE 11751

Sampling point

Ladakh, Likir Village is located at 34°15'56.20"N, 77°11'53.88"E. This material (Fig. 3.39) is locally known as *thabsa* (oven clay) under the local term *dzasa* (Tib. *rdza sa*), also pronounced as 'sesa' or 'sersa'. Sample number in the field: 31. Constructive use: A potter family from Likir⁹² showed the different kinds of clay and explained their particular uses. It was explained as material to make a *thab* (Tibetan stove), meant for interior panelling of *tandoor* stoves. Contrary to sample 11752, this material is mixed with coarse material and appears to be ready for application. The used clay has to fulfil several tasks such as resistance to heat, more or less no shrinkage, no cracking, and no addition of fibres or other organic materials.



Fig. 3.39 Basgo. Sample 11751.
Sample colour (after Munsell):
Dry 10YR 7/2 light grey.
Semi-dry 10YR 6/3 pale brown.

Grain size distribution

Compared with *thabsa* sample 15515, the material is also very fine with just a small amount of sand and gravel, and a high content of silt and clay; biggest fraction: fine gravel. The median is located at app. 3 μm , similar to sample 15515 with app. 2.5 μm ; the <2 μm fraction contains app. 38% of the whole sample, similar to sample 15515 with app. 42%. The content of gravel is 1.8%, and the content of sand is 13.2%. Equalling 15%, the sample shows a small content of coarse material (fine gravel and sand), but this content is still higher than sample 15515 with 3.3%. This may be relevant for the processing of the material with the aim to create a fine layer important for its later use for stove construction. On the other hand, to avoid shrinkage, a relatively high content of silt of 46% is available. The maximum peak again clearly corresponds to the fine silt fraction with 31% versus 42.9% at sample 15515. The grain size distribution graphics show a bimodal distribution with a valley between medium sand and medium silt, which may point towards the addition of sand.

92 The house name of the potter family is Langdopa. The interview with the potter Rigzen Wangyal, his brother Rigzen Angdu and their mother, and Tsering Norbu was held in August 2011 and interpreted by Sonam Wangchuk (cf. Feiglstorfer 2014).

	Gravel	Sand	Silt	Clay [%]
11751 (<i>dzasa</i> , Likir)	1.8	13.2	46	39 (mixed material)
15515 (<i>thabsa</i> , Basgo)	0.1	3.2	54.5	42.2 (raw material)

Grain shapes

The examination of the grain shape shows a continuous change of the dominant rounding from 'angular-shaped' and a 'beginning rounding' in fractions $>2,000\ \mu\text{m}$, 'angular' with a slight tendency towards 'beginning rounding' in fractions $>630\ \mu\text{m}$, and 'angular-shaped' in fractions $>200\ \mu\text{m}$. This fact emphasises the addition of sand to the raw material, probably to avoid cracks after drying and during heating (Fig. 3.40).

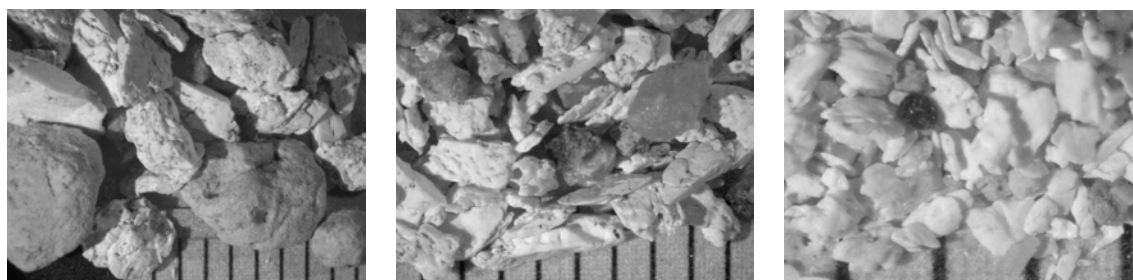


Fig. 3.40 Shapes of grains in sample 11751. Scaled in millimetre (B/W).
Shape of fraction $>2,000\ \mu\text{m}$ (left), $>630\ \mu\text{m}$ (centre), $>200\ \mu\text{m}$ (right).

Bulk mineral analysis

In general the sample is very similar to *thabsa* sample 15515. Only the $7\text{\AA}$ minerals and mica are available in trace amounts, as opposed to the small amount found for sample 15515. The amount of calcite was measured at 12%. The sample has a rather greyish appearance without any traces of a red colouring ferric oxide. The content of gypsum at 12% is rather high and not suitable for the use as a stove or for pottery ware. This relatively large amount does not fit into the picture of clay used for continuous heating (as is the case with a stove). At temperatures of about 100°C to 110°C , gypsum changes into a hemihydrate, and at a temperature of about 200°C , it changes into an anhydrite. When cooling down, humidity is absorbed and recrystallisation occurs.

Either the explanation given to the author about this material was not correct or the collected sample contained some gypsum or was contaminated with gypsum. Since the other material parameters seem to fit to clay used for pottery or stoves, an unwanted collection of a gypsum contaminated material seems obvious. In consideration of this finding, further analysis of this sample is needed. The collection of a new comparable sample from Likir is necessary to verify this examination.

Results measured with STA

- Peaks at 138°C and 145°C point towards the presence of gypsum, measured at 12%.
- The residual mass at $1,000^{\circ}\text{C}$ is 86.09%.

Clay mineral analysis

The CMA shows a less scattered content of clay minerals as observed in most other Basgo-Likir samples, and generally shows similarities to the two other pottery and *thabsa* samples, i.e. 15515

and 11752: Swellable clay minerals and kaolinite are not present, but a big amount of chlorite was determined.

	Smectite	Verm18°	Illite	Kaolinite	Chlorite [%]
11751 (Likir <i>dzasa</i>)	0	0	43	0	57
15515 (Basgo <i>thabsa</i>)	0	0	31	0	69

BASGO / LIKIR – STOVE AND POTTERY CLAY. SAMPLE 11752

Sampling point

Ladakh, Likir Village, located at 34°15'56.20"N, 77°11'53.88"E. This material (Fig. 3.41) is locally known as pottery clay under the local term *dzasa* (Tib. *rdza sa*). Contrary to sample 11751, this is an unmixed raw material. Sample number in the field: 26. Constructive use: Clay used for pottery and for the production of a *thab*.



Fig. 3.41 Likir. Sample 11752.
Sample colour (after Munsell):
Dry 10YR 5/1 grey.
Semi-dry 10YR 4/1 dark grey.

Grain size distribution

Compared with *thabsa* sample 15515, the material is also very fine with just a small amount of sand and gravel, and a high content of silt and clay; biggest fraction: medium sand. The median is located at app. 2.8 μm , similar to sample 15515 with app. 2.5 μm , and sample 11751 with 3 μm ; the <2 μm fraction contains app. 38% of the whole sample, similar to sample 15515 with app. 42%, and to sample 11751 with app. 38%. In this sample gravel is not present and only 0.2% of sand versus sample 11751 with a content of gravel at 1.8% and a content of sand at 13.2%. At 0.2% the total amount of coarse material is very low versus 15% for sample 11751. Again a relatively high content of silt at 60.3% is present compared to 46% for sample 11751, and 54.5% for sample 15515. The maximum peak again corresponds to the fine silt fraction at 36.3%, compared to 31% for sample 11751, and 42.9% for sample 15515. The grain size distribution graphics show no valley as in sample 11751. Since the material was taken directly from the pit, the addition of material in this sample can be excluded. According to the results of the grain size analysis, pottery clay sample 11752 seems to be equal to pottery clay sample 11751 but without the addition of sand.

	Gravel	Sand	Silt	Clay [%]
11752 (<i>dzasa</i> , <i>Likir</i>)	0	0.2	60.3	39.5 (raw material)
15515 (<i>thabsa</i> , Basgo)	0.1	3.2	54.5	42.2 (raw material)
11751 (<i>dzasa</i> , <i>Likir</i>)	1.8	13.2	46	39 (mixed material)

Grain shapes

Grain shapes between 2,000 μm and 200 μm are dominantly ‘angular-shaped’ and continuously have the same rounding, indicating no evidence of a mixture.

Bulk mineral analysis

The results of the BMA are more or less the same as for pottery clay sample 11751. Just the gypsum is missing, which may emphasise the afore-mentioned hypothesis that sample 11751 may have been contaminated with gypsum and was originally similar to sample 11752, i.e. without a content of gypsum. The content of calcite was measured at 8% and a content of dolomite at 2%, as shown in Table 3. A content of hematite gives this sample a reddish appearance.

Clay mineral analysis

The CMA shows again close similarity between sample 11752 and sample 11751. Within the Basgo-Likir samples, two further samples, i.e. 11948 (adobe brick from the Lotsāba Lhakhang in Basgo) and 11952 (new brick from Basgo), show similarities to sample 11752. Such similarities are a corrensite mixed layer, no vermiculite and a strongly marked chlorite.

	Smectite	Verm18°	Illite	Kaolinite	Chlorite [%]
11752 (Likir <i>dzasa</i>)	0	0	38	0	62
15515 (Basgo <i>thabsa</i>)	0	0	31	0	69
11751 (Likir <i>dzasa</i>)	0	0	43	0	57

In consideration of the fact that these samples are too coarse, such similarities can also lead to the assumption that samples 11948 and 11952 (both samples used for adobe bricks, in short mentioned as AB) are useful as pottery clay in the case that the fine material can be separated.

11952 (AB Basgo)	20	0	47	2	31
11948 (AB Lotsāba Lk.)	28	0	44	2	27

After analysis, we can state that sample 11752 and 11751, both of which are used for pottery, are very similar, with the difference being that the latter was mixed with a small amount of sand (13.2%) for stabilisation purposes.

LIKIR – CLAY PIT AND ADOBE BRICK. SAMPLE 11763

Sampling point

Ladakh, Likir Village, the pit is located at app. 34°15'28.53"N, 77°12'31.30"E. At the entrance to the village, a clay pit was dug for the primary use of collecting water and not for the collection of raw material. Since this water hole enabled access to material from the area of the ground water, a sample was taken and examined (Fig. 3.42). Sample number in the field: 27.



Fig. 3.42 Likir. Sample 11763.
Sample colour (after Munsell):
Dry 7.5YR 5/1 grey.
Semi-dry 2.5YR 2.5/1 black.

Grain size distribution

The material is relatively coarse, with the biggest fraction being fine gravel. The median is located at app. 130 μm ; the $<2 \mu\text{m}$ fraction contains app. 14% of the whole sample. At 60.9%, the total amount of coarse material (gravel and sand) is relatively high. At 22.7%, the maximum peak again corresponds to the medium sand fraction. The grain size distribution graphics show no valley or sharp break. In regard to this grain size distribution, one cannot assume addition of coarse material. A comparison with the samples of the Basgo-Likir group is given below. The results show a close similarity to mixture 8465 from Basgo which was used for making the flat earth roof on the Maitreya Lhakhang.

	Gravel	Sand	Silt	Clay [%]
11763 (Likir clay)	7.1	53.7	25.5	13.7
8465 (<i>dzasa+thetsa</i>)	12.5	50.8	25.8	10.9

Grain shapes

The grain shapes were examined as ‘very angular’ and do not give any evidence of a mixture of different materials.

Bulk mineral analysis

The results of the BMA fit into the general appearance of clay in the Basgo-Likir region. Compared with sample 8465 (*dzasa + thetsa*: flat roof material from Basgo), which shows similarities in grain size distribution (see analysis before), there are only slight differences in the missing of 14Å minerals or in the slightly less availability of 7Å minerals and phyllo silicates. The content of calcite was measured at 8%, as shown in Table 3; gypsum and dolomite are not present. The sample material is relatively dark, particularly already appearing almost black in the semi-dry constitution, a possible indicator of organic content.

Clay mineral analysis

The CMA shows with 6% a relatively low content of swellable clay minerals but it stands out with a relatively high amount of illite. The list given below again shows a comparison with samples of the Basgo-Likir group. The sample has with 63% (!) a significantly high amount of illite, some chlorite and kaolinite, and a small amount of smectite.

	Smectite	Verm18°	Illite	Kaolinite	Chlorite [%]
11763 (Likir clay)	6	0	64	14	16
8465 (<i>dzasa+thetsa</i>)	18	11	51	4	16

LIKIR – CLAY PIT AND ADOBE BRICK. SAMPLE 11921

Sampling point

Ladakh, Likir Village, the pit is located some metres beside the water whole, from where sample 11763 was taken at app. 34°15'28.53"N, 77°12'31.30"E (Fig. 3.43). Beside this clay pit, adobe bricks, which were processed from this material, are stacked. Sample number in the field: 28. Constructive use: Raw material for adobe bricks.



Fig. 3.43 Likir. Sample 11921.
Sample colour (after Munsell):
Dry 7.5YR 7/3 pink.
Semi-dry 7.5YR 5/3 brown.

Grain size distribution

The material is relatively fine, with the biggest fraction being fine gravel. The median is located at app. 8.5 μm versus app. 130 μm for sample 11763; the <2 μm fraction contains app. 29% of the whole sample versus 14% for sample 11763. At 10.6%, the total amount of coarse material (gravel and sand) is relatively low versus 60.9% for sample 11763. At 27.3%, the maximum peak corresponds to the coarse silt fraction. The grain size distribution graphics show a bimodal distribution. The addition of coarse material can be excluded regarding this material as raw material taken from the pit. The raw material seems to be rather fine for the preparation of adobe bricks, which must be the reason for its later mixture with sand.

	Gravel	Sand	Silt	Clay [%]
11921 (Likir clay pit)	0.5	10.1	60.3	29.1
11763 (Likir clay)	7.1	53.7	25.5	13.7

Grain shapes

With 'very angular' shapes, the grain shape follows the result observed for sample 11763, giving no evidence for a mixture.

Bulk mineral analysis

The results of the BMA fit into the general appearance of clay of the Basgo-Likir samples. Compared with sample 11763 (adobe brick from Likir), the appearance is similar, although some differences can be traced: 14Å minerals appear as traces, phyllo silicates appear in small amounts instead of traces, and plagioclase appears in a smaller but still high amount when evaluated against sample 11763. Compared with sample 11763, calcite is not present.

Clay mineral analysis

The CMA shows a much higher content of swellable clay minerals (smectite with just 35%) than found in sample 11763 from Likir. Significant for this sample is a clear amount of illite, no vermiculite, a small amount of kaolinite, and chlorite of a subordinate amount.

	Smectite	Verm18°	Illite	Kaolinite	Chlorite [%]
11921 (Likir clay pit)	35	0	49	6	10
11763 (Likir clay)	6	0	63	14	16
11752 (Likir <i>dzasa</i>)	0	0	38	0	62

In comparison with another type of clay from Likir (sample 11752) known as *dzasa* (pottery clay), sample 11921 shows much more smectite, much less chlorite, more illite and a coarser grain size distribution as shown in a juxtaposition of the grain sizes and CMA of both samples.

- 11921 (GSD) The median is located at app. 8.5 µm; the <2 µm fraction contains app. 29%.
- 11752 (GSD) The median is located at app. 2.8 µm; the <2 µm fraction contains app. 38%.

LIKIR – SAND. SAMPLE 11749

Sampling point

Ladakh, Likir Village, located at 34°15'56.20"N, 77°11'53.88"E. This type of sand (Tib. *bye ma*) can be found close to the pits for *thabsa* sample 11752 (Fig. 3.44).⁹³ It is locally known as sand for mixing with pottery clay for adobe bricks. For these mixtures not just any sand is used; instead this sand in particular is preferred. Sample number in the field: 23. Constructive use: Sand for mixing for pottery ware, and sand to be mixed with clay for adobe bricks.

Grain size distribution

As 'sand', the material is dominated by medium and fine sand, with the total amount being 74.3%. However, a small amount of silt and clay is also present. The median is located at app. 150 µm; the <2 µm fraction contains app. 7% of the whole sample. At 0.6%, the amount of gravel is very low. The peak corresponds to the fine sand fraction. Compared with *thabsa* sample 11752, with which it is originally mixed on site, and *thabsa* sample 15515, with which it is mixed for the test within this study (see below), these comparative samples are also relatively fine with just a small content of sand and gravel and a high content of silt and clay. Both samples 11752 and 15515 show their biggest fraction as being medium sand and their smallest fraction also as fine clay. In this relation, the sand (sample 11749) seems to be an appropriate complementation.

93 The sample's origin is described in Feiglstorfer 2014: 369.



Fig. 3.44 Likir. Sample 11749.
Sample colour (after Munsell):
Dry 5YR 5/3 and 5YR 6/3 olive and
pale olive.
Semi-dry 5YR 6/3 pale olive.

	Gravel	Sand	Silt	Clay [%]
11749 (Likir sand)	0.6	78.5	14.8	6.1

Grain shapes

The grain shapes were examined as ‘angular’ and do not give any evidence for a mixture of different materials.

Bulk and clay mineral analysis

The results of the BMA show traces of mica, small amounts of quartz and K-feldspar (marked in Table 3 with *), and medium amounts of amphiboles and plagioclase (marked in the list with **). Results of the BMA and of the CMA show close similarities to the clay collected from the water hole.

The clay mineral analysis shows a small amount of swellable clay minerals, which influence the behaviour of the mixture. This may be the reason why potters from Likir prefer this sand. It may also be the suitable material for preparation of a clay plaster. The content of smectite indicates this material being of a rather young genesis. At 4%, the content of kaolinite is relatively small. The content of illite points towards an older material as opposed to young material, which was probably crunched during the Ice Age.

	Smectite	Verm18°	Illite	Kaolinite	Chlorite [%]
11749 (Likir sand)	4	0	66	4	26
11763 (Likir clay)	6	0	63	14	16

The trace content of calcite may give an answer to the continuously recurring question of whether calcite was added by humans or if it was an already naturally given component. To get closer to an answer, an observation of calcite as anthropogenically added or naturally mixed is conducted in the following.

4. ADDITIONAL EXAMINATIONS OF SELECTED EXAMPLES

4.1 Behaviour of stove material during heat treatment

Tandoor stoves are widely known throughout the Asian continent. Heat is produced with wood or charcoal and reaches temperatures of up to 600°C–800°C (Katz, Weaver 2003: 254). Temperatures for preparing meat and bread (e.g. Indian *nan* or *chapatti*) must be much lower. Om Gupta (2006: 2393) describes the heat used for firing a clay stove being at a temperature of up to 480°C. Since the temperature has to be kept for an extended period of cooking, a long lasting heat resistance is important. Essential is the heat, not the flames, the latter of which should be avoided as much as possible. Also the design and material of *tandoor* stoves differ widely. *Tandoor* stoves are popular among members of the Indian army based in Ladakh.⁹⁴ The given form is that of a cylindrical oil barrel with the inside coated with clay. According to local saying, before processing of the clay, it is mixed with fine sand at a ratio of app. 1:2 (Feiglstorfer 2014: 370).

For a traditional *tandoor* stove, the fire is made through a bottom hole. The food for cooking is put into the oven from the top. A traditional *tandoor* stove made of clay is also widely known. In Punjab (e.g.) the tradition of using clay stoves is still vivid, and the same can be said for the Lower Himalayas, e.g. in the area of Manali. Since the practice of preparing *tandoor* stoves in metal barrels is relatively young, the *tandoor* made from an oil barrel can be explained as a composite development of the *tandoor* tradition from other areas of India – possibly transferred to Ladakh by soldiers – and the old Ladakh stoves tradition of working with heat resistant clays (*thabsa*).

For sample 11751, we find a *tandoor* stove clay mixture with material properties that appear similar to sample 15515 but with a slightly higher content of sand. Since the use of sample 11751 was only uncovered from interviews with locals and not seen when mixed or further processed, the following examinations should provide an insight into the material's shrinking behaviour at different temperatures, i.e. 240°C, 480°C, 600°C and 950°C.⁹⁵ For further comparison, the tests will be conducted with two different kinds of stove material (*thabsa*):

- With the raw material of sample 15412 from Tunlung near Basgo (see mineral analysis).
- With the raw material of sample 15515 from Basgo (see mineral analysis).
- With a mixture of the raw material (sample 15515) and the fine sand of Likir – which is known as material for mixing for the preparation of clay for an oven or for pottery ware and which was locally used to prepare sample 11751 – we receive the finally processable material from Likir.

In order to find the right proportion in the addition of sand from Likir (sample 11749) so that we achieve a *dzasa* mixture similar to sample 11751, the following experiment was conducted.

94 The use of a particular clay for coating the inside of an oil barrel was described by locals, and raw material for that purpose was given to the author by the potter's family from Likir.

95 240°C was chosen as average cooking temperature, which ranges in a clay stove between 200°C and 240°C. 480°C was chosen as the temperature described by Om Gupta (2006) for a clay oven. 600°C was mentioned by Katz and Weaver (2003) as a temperature reached with coal and charcoal. 950°C is the temperature at which sintering begins.

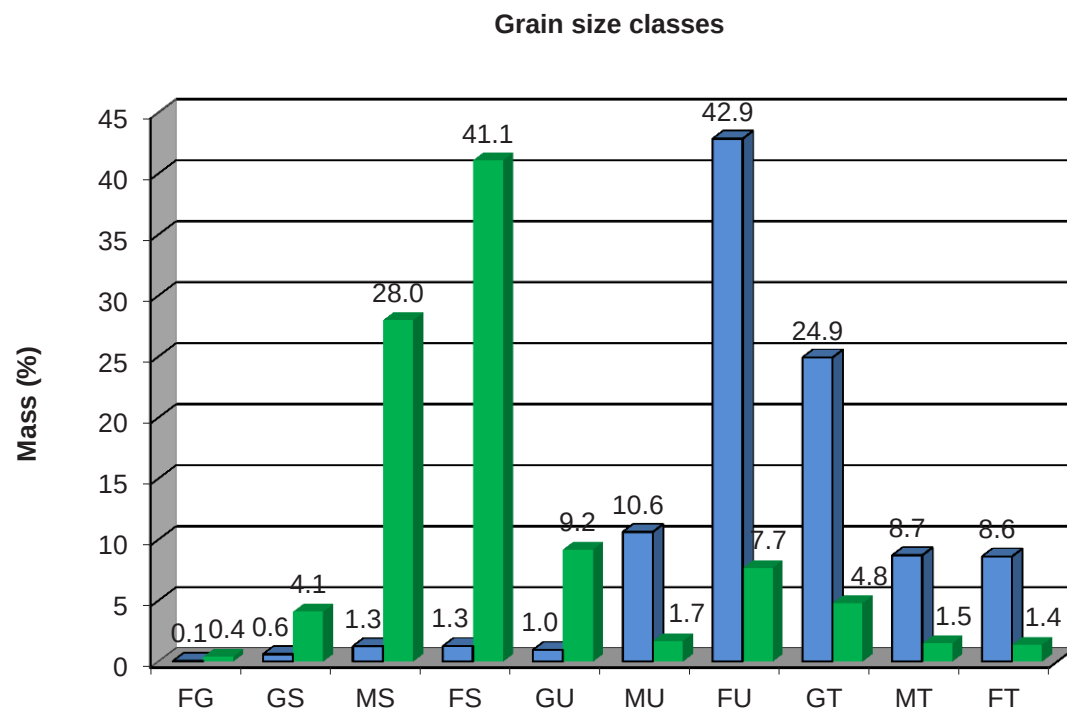
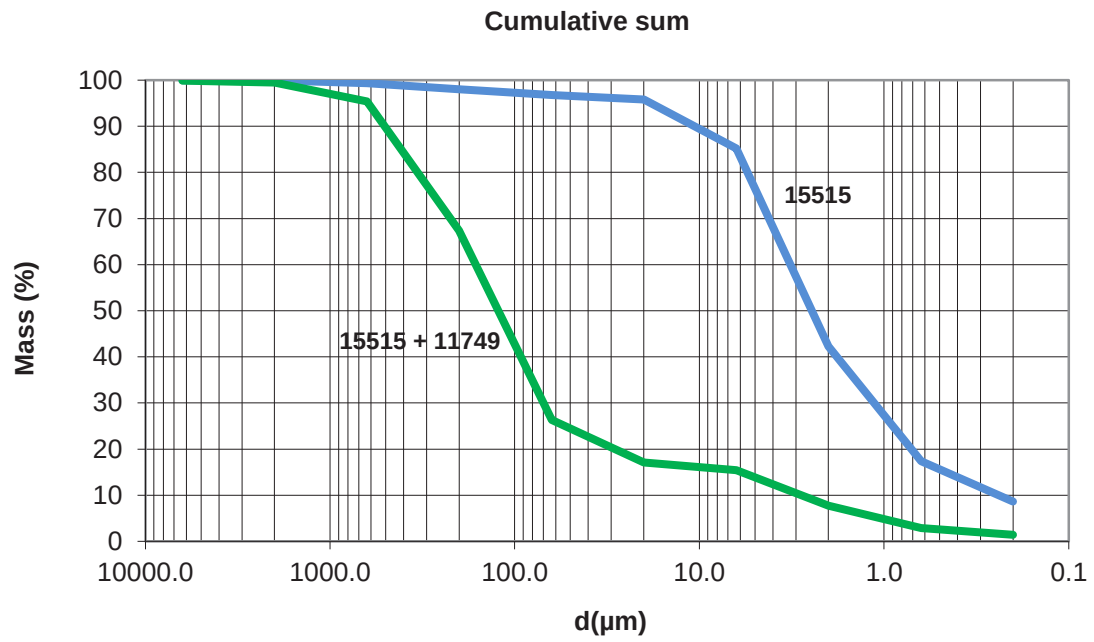


Fig. 3.45 *Tandoor* stove clay: Sample 15515 (raw material; blue colour) in comparison to a mixture with sample 11749 (sand; green colour).

Comparing the grain size distributions between samples 15515 and 11751, the main difference is in the fractions sand and gravel (see Appendix Chapter III). The calculation shows effects on the whole mixture by changing the ratio of these two fractions.

	Gravel	Sand	Silt	Clay [%]
15515 (<i>thabsa</i> , Basgo)	0.1	3.2	54.5	42.2 (raw material)
11749 (sand, Likir)	0.6	78.5	14.8	6.1 (raw material)
11751 (<i>dzasa</i> , Likir)	1.8	13.2	46	39 (mixed material)

Content of grain sizes $\geq$ (sand and gravel), same as $>$ coarse silt (in Fig. 3.45 marked with GU):

- Sample 15515 contains app. 3.3%.
- Sample 11749 contains app. 79.1%.
- Sample 11751 contains app. 15%.

About 12% of the total mass of the whole sample with a grain size $>$ GU has to be added to sample 15515 to achieve a mixture with a grain size distribution in the fractions $>$ GU, similar to sample 11751. As a first attempt, estimated 15% of the total mass of the fractions $>$ GU of sample 15515 were taken from Likir sand sample 11749 and added to sample 15515. The resulting grain size distribution as given in Fig. 3.45 shows a considerable increase of sand, on the one hand, and of silt and clay, on the other hand: The amount of sand in sample 15515 mixed with sample 11749 rises up to 73.6%, which is close to sample 11749 with 78.5%, while the content of silt decreases from 54.5% (in sample 15515) to 27.5% (in the mixture) and the content of clay from 42.2% to 7.7%, respectively. A comparison with the *dzasa* (i.e. sample 11751) shows that the addition of 15% of the total mass of the fractions $>$ GU of sample 15515 was too much and needs to be reduced to receive a proper mixture, which is equivalent to the *dzasa* from Likir.

The following juxtaposition shows the different shrinkage behaviour for three selected samples, i.e. 15412 (*thabsa* / Tunlung), 15515 (*thabsa* / Basgo) and 15515 + 11751 (*thabsa* / Basgo + sand / Likir) as shown in Fig. 3.45). Figs. 3.46 to 3.55 show a juxtaposition of the visual appearance of samples 15412 (*thabsa* / Tunlung) and 15515 (*thabsa* / Basgo) after firing. In the following table, columns marked with Dry* give the values for drying shrinkage, and those marked with °C give the values for firing shrinkage.

Shrinkage; change of the length of the samples [cm]:

	Wet	Dry*	240°C	480°C	600°C	900°C
15412	20	19.50	19.50	19.45	19.45	19.45
15515	20	18.10	18.10	18.07	18.00	17.65
15515+sand	20	18.30	18.30	18.30	18.30	18.05

Shrinkage [%]

	Dry*	240°C	480°C	600°C	900°C
15412	2.50	2.50	2.75	2.75	2.75
15515	9.5	9.5	9.65	10.0	11.75
15515+sand	8.5	8.5	8.5	8.50	9.75

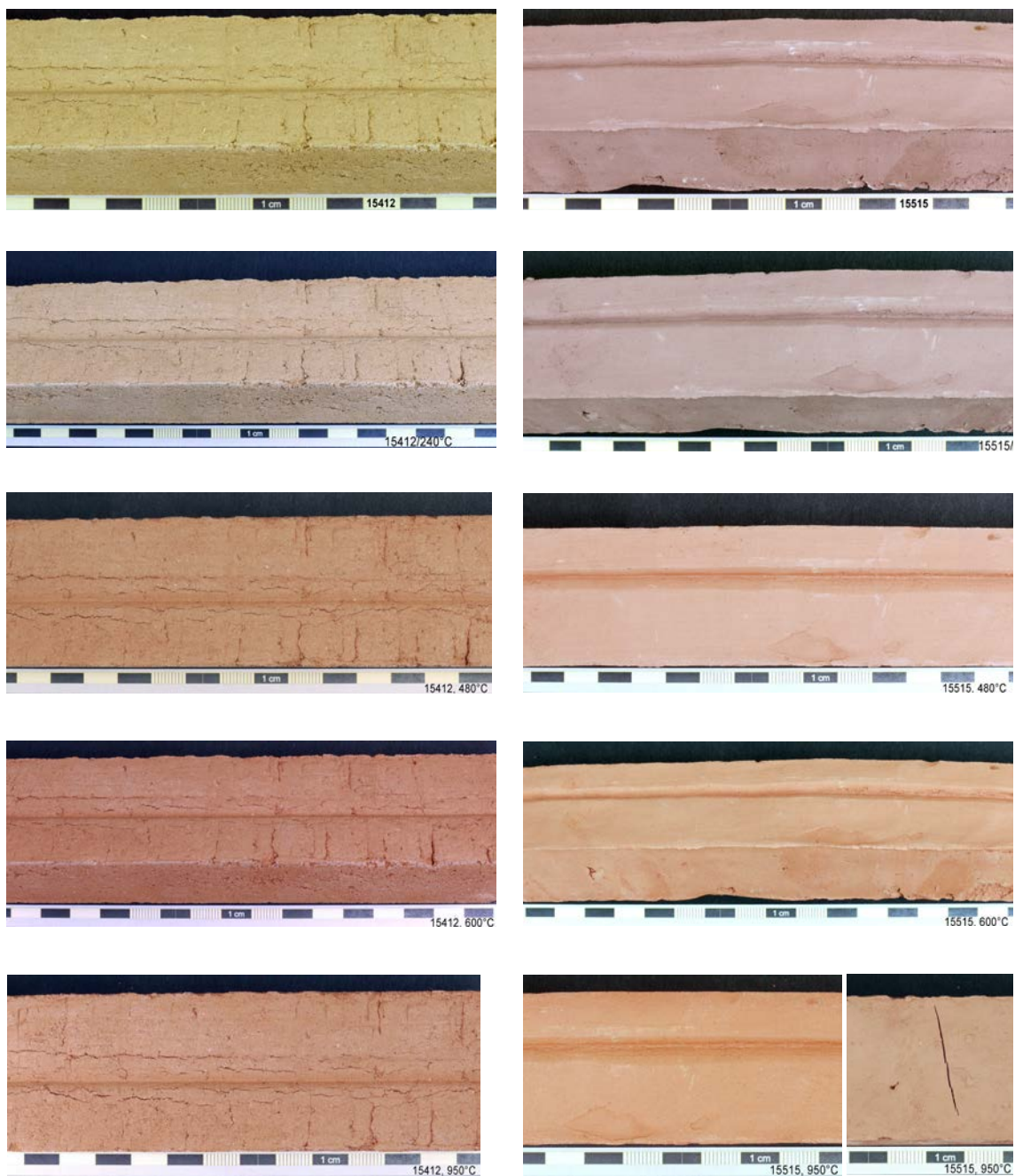


Fig. 3.46 (Top left) 15412. Unfired.

Fig. 3.48 (Second left) 15412. Fired at 240°C.

Fig. 3.50 (Third left) 15412. Fired at 480°C.

Fig. 3.52 (Fourth left) 15412. Fired at 600°C.

Fig. 3.54 (Bottom left) 15412. Fired at 950°C.

Fig. 3.47 (Top right) 15515. Unfired.

Fig. 3.49 (Second right) 15515. Fired at 240°C.

Fig. 3.51 (Third right) 15515. Fired at 480°C.

Fig. 3.53 (Fourth right) 15515. Fired at 600°C.

Fig. 3.55 (Bottom centre / right) 15515. Fired at 950°C:
Front side of the sample (centre) / back side of the sample (right).

4.1.1 Analysis of the shrinkage

- Sample 15412 (*thabsa* / Tunlung) shows the ideal behaviour after three days of drying and then firing. Shrinkage after drying is 2.5% and remains nearly the same (2.75%) until the end of firing when temperatures reach 900°C. Regarding shrinkage behaviour, this material from Tunlung is ideal for making a stove.
- Sample 15515 (*thabsa* / Basgo) shows shrinkage of 9.5% after three days of drying, while the addition of sand reduces the shrinkage to 8.5%. After firing at 900°C, shrinkage is 11.75%, while the addition of sand reduces this shrinkage to 9.75%. During the different steps and after three days of drying and then firing up to 600°C, nearly no change in shrinkage is visible. This continuity changes between 600°C and 900°C, where further shrinkage is visible. The main shrinkage with and without adding sand happens during the change from the wet state into the dry state but not during firing. Shrinkage during the whole firing process was between app. 1% (with sand) and 2% (without sand).

In this context, sample 15515 (used for *tandoor* stove) shows no firing shrinkage from the point of being in a dry state to firing up to 600°C. In this case the material in an unaltered state would already be suitable in view of its shrinkage. In the case of pottery and stove making, this would mean a possible appearance of cracks due to shrinkage during the drying process, not during firing. In the case of making a stove, these cracks can be filled with moistened clay, though this is not the case for pottery making, where the unfired pottery ware has to be free of cracks. For that reason, the amount of sand has to be slightly increased. Regarding the shrinkage behaviour in a laboratory test, the addition of sand with 15% of the whole mass of the sample appeared as too much. The content of sand within the sample increases and in contrast the content of silt and clay decreases – all these deviations being too high when comparing the result to the values given in the *dzasa* sample 11751. The examination of various mixtures of different types of clay with varying amount of sand should be the aim for future tests.

4.1.2 Behaviour of the surface during the shrinkage test

- For sample 15412 (*thabsa* / Tunlung), during firing at 240°C the colour changes from ochre to a relatively dark grey, and for firing at temperatures up to 950°C, the colour becomes more reddish in appearance (Figs. 3.46, 3.48, 3.50, 3.52, 3.54). The surface is more porous and coarser than in sample 15515. Cracks are visible and must be filled with moistened clay. Cracks appear stable throughout the entirety of the shrinkage test. Cracks that appeared before firing do not change until the end of heating.
- Sample 15515 behaves partially differently. It also reaches its darkest stage at 240°C with a reddish-purple appearance. When firing above 240°C, the colour brightens, becomes more red and remains similar until the end of firing at 950°C (Figs. 3.47, 3.49, 3.51, 3.53, 3.55). It feels smooth, and the sound is high when knocking with one's fingernail on the surface. Between 600°C and 950°C, one crack occurred at the back side of the sample (Fig. 3.55).

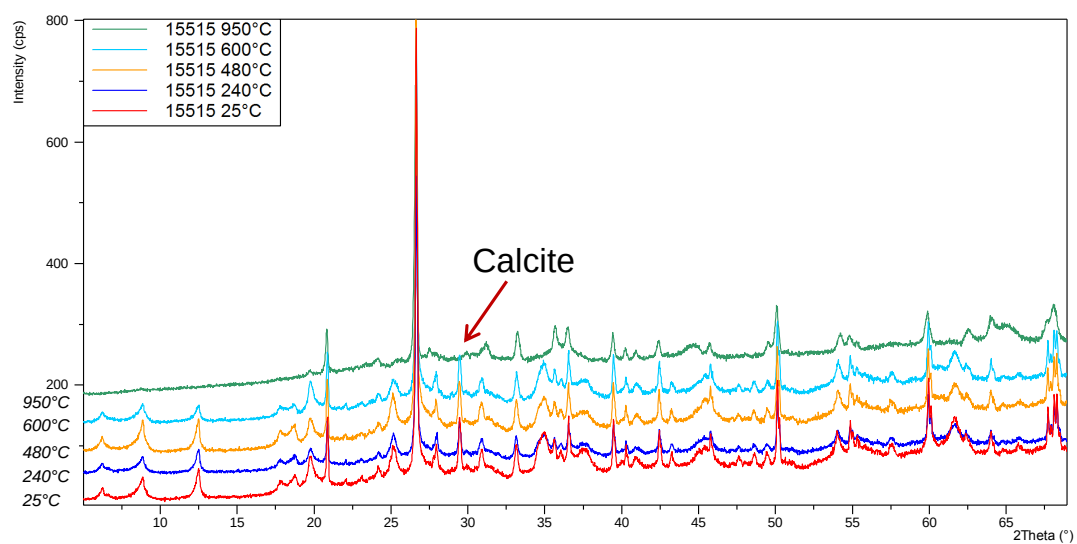
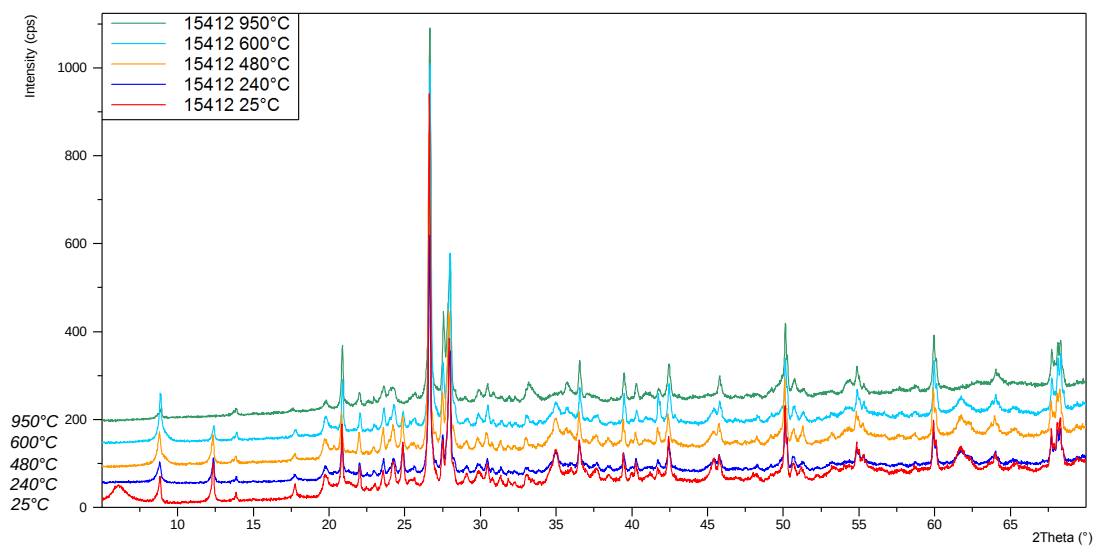


Fig. 3.56 (Top) BMA of sample 15412 at different stages of firing.

Fig. 3.57 (Below) BMA of sample 15515 at different stages of firing.

4.1.3 Influence of minerals on the samples' behaviour during firing

- Comparing the diffractograms of the single stages of firing, the following results can be given (Figs. 3.56, 3.57).
 - For sample 15412, when firing up to 240°C, the peaks become generally slightly smaller and remain similar up to 600°C. Above 600°C, quartz remains unchanged. This sample does not contain calcite. For sample 15412, smectite and vermiculite disappear when firing at 240°C.
 - For sample 15515, the resulting curve remains constant up to 600°C. Above 600°C, quartz and some mica remain, along with K-feldspar and plagioclase. Calcite disappears at app. 800°C (Lasser, Redl 2013: 29).
- Sample 15515, which is used for pottery, shows a content of calcite. For the firing process this content may be one essential factor for heat resistance. In comparison, according to Noll (1984), the clay used in ancient times was rich in calcite to increase strength when fired at low temperatures and to reduce the danger of layers of paint spalling off (Rösch 2010: 8 according to Noll 1984: 43).

As is the case for sample 15412 (*thabsa* / Tunlung), the content of kaolinite influences the behaviour of the clay during firing. Also an increased content of ferric oxides, which is present in sample 15515 as hematite and in sample 15412 as goethite, enables firing at higher temperatures (Wimmer-Frey et al., forthcoming). Phyllo silicates are dispersed at 900°C, while K-feldspar remains stable up to 1100°C (Lasser, Redl 2013: 29).

A high content of quartz is a disadvantage if the stove is often fired. Due to an increase in volume during recrystallisation at the quartz inversion, an increasing content of quartz needs more space. Both samples (15412 and 15515) contain a small amount of quartz.

4.1.4 Content of humidity to reach the 'norm stiffness'

The following list shows the content of humidity in the state of its 'norm stiffness'.

	15412	15515	15515+11749	11748
A. Sample wet in %	44.8	38.4	11.3	22.5
B. Sample dry in %	37.7	27.2	8.2	19.1
C. Humidity in gram	7.1	11.2	3.1	3.4
D. Humidity in % (geotechnical)	19	41.5	37.7	17.8

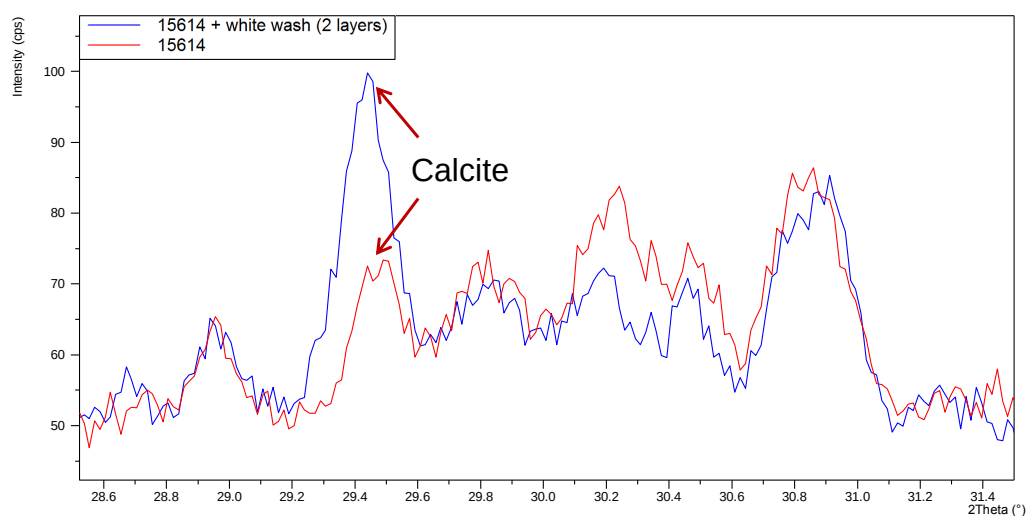


Fig. 3.58 Sample 15614 is a modern plaster produced according to DIN requirements. The curves show one sample without the addition of whitewash compared with a sample with two layers of whitewash.

4.2 Calcite as an anthropogenic or natural factor

A question arises whether the necessary content of calcite in a sample is the result of an anthropogenic addition of calcite or naturally given. Reasons for an anthropogenic addition are whitewashing, preparation of the base layer for a mural painting or stabilisation of clay. During analysis, all samples containing possible remains of whitewashing or a base layer for mural paintings were ground together with the whole sample of clay. Meaning, the analysed contents of calcite were part of the whole analysed sample, which itself could contain natural deposits of calcite. A content of calcite in a sample of a plaster may originate from a natural deposit but also could be remnants of former whitewashing.

Thus, plaster sample 15614 was first measured without whitewashing and subsequently ground and analysed. Thereafter, sample 15614 (1.3 cm thick) was prepared with two layers of a whitewash made of calcite. A comparison of the content of calcite in both samples is given in Fig. 3.58. The measured difference of the content of calcite between the two samples (with and without whitewash) is app. 1%. Since most of the examined Himalayan layers of plasters are of a thickness of up to app. 4 cm with a layer thickness of whitewash of up to app. 50 μm , the measureable content of calcite of the whole plaster sample shrinks proportionally. On the other hand, we may also state that in general the whitewashing was and still is part of a collective annual renewing process – also used in a ritual context – and over dozens and even hundreds of years many layers of whitewash may have been applied but also washed away by precipitation and disappeared as a result of weathering. Nevertheless, according to the given result of this examination, we can state a difference of calcite between the raw material and the state of being whitewashed with two layers of app. 1% for a 1.3 cm thick plaster after graining the whole sample (i.e. clay plaster + two layers of whitewash). This also means that a content of calcite in the range of more than app. 1% on a whitewashed plaster of a thickness of 1.3 cm may already result from a natural deposit in the raw material. As long as we do not separate the calcite layer from the plaster layer below in separate examinations, it is not possible with methods of BMA, Scheibler test and STA, to give a more

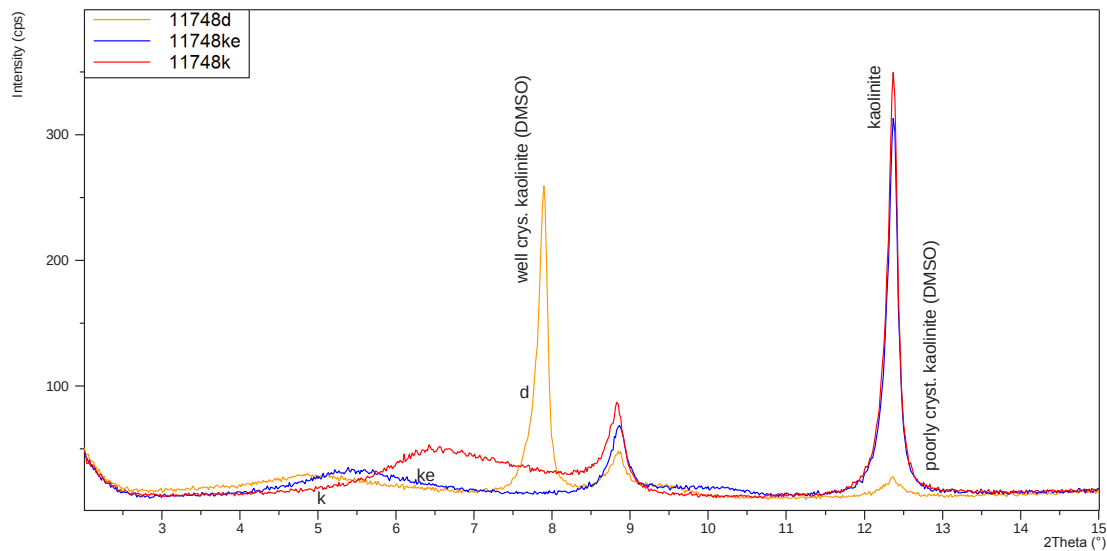


Fig. 3.59 GMA. Sample 11748. Content of well-crystalised kaolinite.

detailed statement regarding the content of anthropogenically applied calcite. As an example, the BMA of sample 8479 (pillar plaster) shows a calcite amount of 11%. In this case we can state that a naturally given content of calcite is existent, but we may not also exclude an anthropogenic addition. White layers on plasters may point towards the use of calcite in a comparably small amount, as shown in Fig. 3.58. Indications for an anthropogenic addition would result from a case, for example, where the lower layer of the plaster is prepared without calcite and the fine upper plaster layer with calcite. Since some samples of interior plasters originate from ruins without a roof, weathering is a reason for the disappearance of calcite from the surface, even of former interior plasters. Being that weathering due to precipitation is not uniform over the whole surface of the wall, results of mineral analyses may vary.

Gypsum in comparison: In the case of gypsum as a base layer for a mural painting, the influence of weathering is similar but with an even quicker effect. This is particularly true at ruins without a protective roof. Since in one liter of water two grams of gypsum can be dissolved, in the case of precipitation the weathering of a gypsum surface happens rather quickly.

4.3 Content of kaolinite

A relatively high content of kaolinite was stated for the samples from Tunlung and Ne, as shown in the CMA graphics (Fig. 3.59). In the X-ray diffraction, the kaolinite peaks in the potassium and potassium-ethylen curve at about $7\text{\AA}$ split up in the DMSO curve. The high peak at $11.2\text{\AA}$ (7.8°) points towards the content of well-crystalised kaolinite, and the remaining broader and much smaller peak at $7\text{\AA}$ (12.5°) points towards the content of poorly crystallised kaolinite. This could be proved for all stove samples (11748, 15412 and 11919). The IRS analysis confirms the X-ray measurement. Figs. 3.60 and 3.61 show the results for the IR-measurements. The four peaks at a wave number between about 3694 and 3620 cm^{-1} are evidence for a well-crystalised kaolinite (cf. van der Marel and Beutelspacher 1976). With the Infrared Spectroscopy (IRS) analysis several other minerals such as smectite and quartz were also traced.

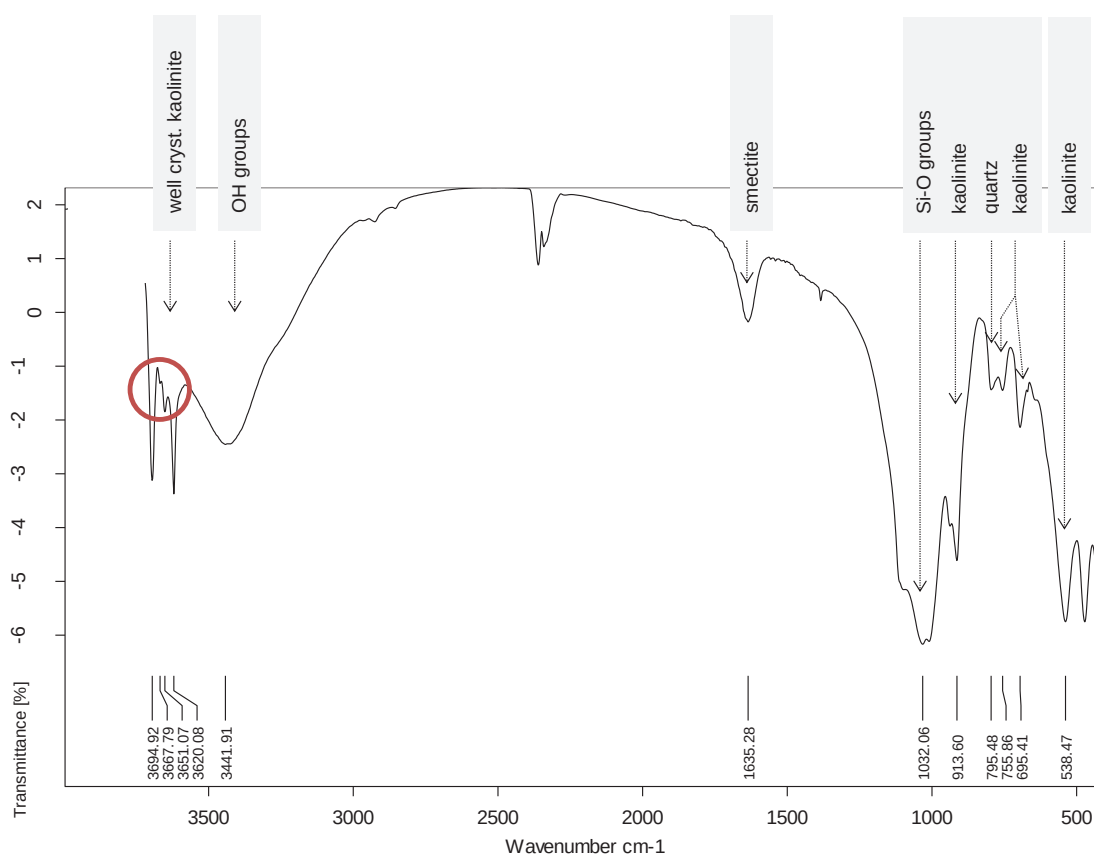


Fig. 3.60 Sample 11748. IRS analysis. See Fig. 3.61 for the detail of the molecular structure marked by a circle.

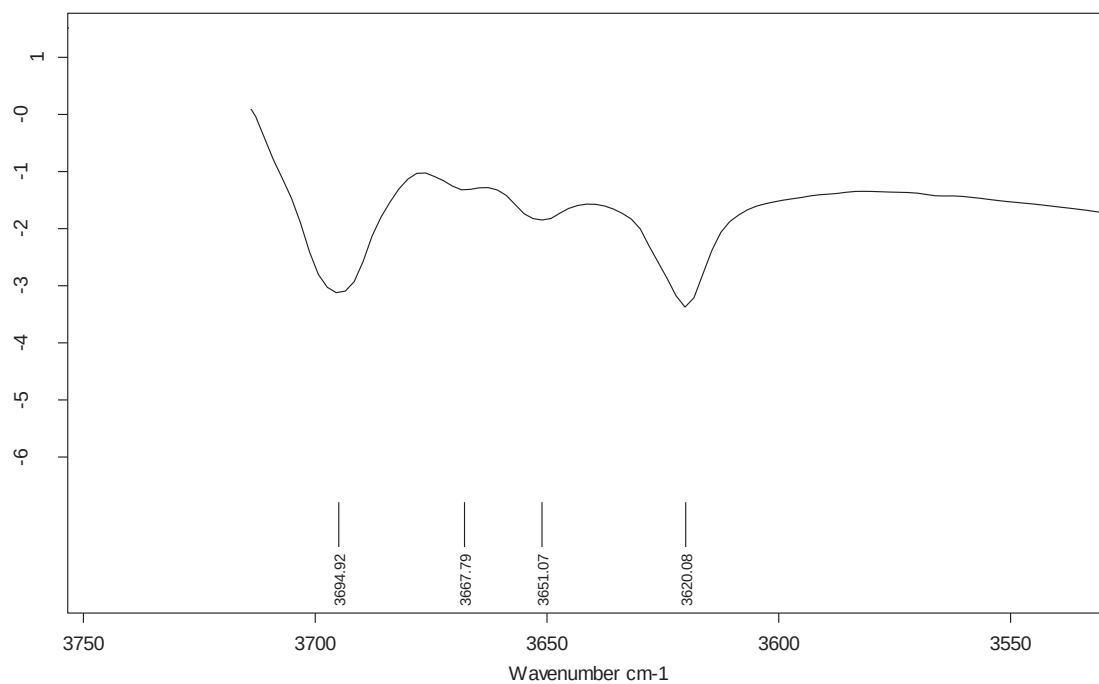


Fig. 3.61 Sample 11748. IRS analysis. Detail of Fig. 3.60. Content of well-crystalised kaolinite according to van der Marel and Beutelspacher 1976.

4.4 Tables of results

Table 3.2 Grain size classes.

Sample	Gravel [%]	Sand [%]	Silt [%]	Clay [%]	Median [µm at 50%]	<2µm [%]
Basgo – Maitreya Lhakhang						
8469	0.8	32.2	55.2	11.8	22	12
8479	2.7	48.9	31.8	16.6	70	17
8496	17.3	41.9	30.0	10.8	130	11
Basgo – Lotsāba Lhakhang						
8482	0.5	7.0	67.7	24.8	5.5	24
8483	0.9	8.1	64.9	26.1	4.8	26
11946	5.2	16.3	62.9	15.6	9	17
11948	17.2	51.0	21.8	10.0	220	10
Basgo – Lhakhang close to road (Highway NH1D)						
8475	6.5	33.1	42.6	17.8	20	18
11928	7.3	29.7	42.1	20.9	15	21
8499	7.5	39.6	41.3	11.6	50	12
8472	35.8	42.5	14.2	7.5	550	8
11933	10.4	60.4	18.8	10.4	180	10
Basgo – building raw material						
15410	53.9	8.7	30.7	6.9	2000	8
11915	3.8	74.1	14	8.2	250	9
15411	6.0	68.8	16.5	8.7	240	9
8465	12.5	50.8	25.8	10.9	210	11
11952	6.7	35.5	38.7	19.3	31	19
Basgo – clay stove (<i>thab</i>)						
11748	31.8	44.7	15.6	7.9	650	9
15412	23.7	39.5	22.8	13.9	180	14
11919	21.2	44.1	24.3	10.3	380	10
Basgo / Likir – stove and pottery clay						
15515	0.1	3.2	54.5	42.2	2.5	42
11751	1.8	13.2	46	39	2.5	38
11752	0	0.2	60.1	39.5	2.8	38
Likir – adobe brick and clay pit						
11763	7.1	53.7	25.5	13.7	130	14
11921	0.5	10.1	60.3	29.1	8.5	29
Likir – sand						
11749	0.6	78.5	14.8	6.1	150	7

Table 3.3 Results of the bulk mineral analysis.

Sample	14Å	Mica	Amph	7Å	Phy sil	Quar	Goeth	K-fsp	Plagio	Calc	Dol	Hem	Gyps	Pyr
Basgo – Maitreya Lhakhang														
8469	.	.	*	*	*	*	---	*	*	7.8%	---	.	---	.
8479	.	.	*	*	*	**	---	*	**	11.3%	---	.	---	---
8496	.	.	*	*	*	*	---	**	***	8%	---	.	---	---
Basgo – Lotsāba Lhakhang														
8482	.	.	*	*	*	*	---	*	**	6%	---	.	2%	---
8483	.	*	*	*	*	*	---	*	**	6%	---	.	2%	---
11946	---	.	*	*	.	*	---	*	**	10%	---	---	.	---
11948	.	.	---	*	.	*	---	*	*	11%	---	---	---	.
Basgo – Lhakhang close to road (Highway NH1D)														
8475	.	*	*	*	.	*	---	*	**	13%	.	.	2%	---
11928	.	.	*	*	.	*	---	*	*	12%	2%.	.	.	.
8499	.	*	*	*	.	*	---	*	**	15%	3%.	.	---	---
8472	.	.	*	*	.	*	---	*	**	12%	.	---	.	.
11933	.	.	*	*	.	*	---	*	**	13%	1%.	---	---	.
Basgo – building raw material														
15410	.	.	.	*	.	*	---	.	*	10%	1%.	.	---	---
11915	---	.	---	.	.	*	---	*	**	7%	---	.	---	---
15411	.	.	.	*	.	*	---	**	**	11%	---	.	---	---
8465	.	.	*	*	*	*	---	**	***	10%	.	.	.	---
11952	.	.	.	*	*	*	---	*	*	11%	1%.	.	---	---
Basgo – clay stove (<i>thab</i>)														
11748	*	*	---	**	*	*	.	*	*	---	---	.	---	---
15412	*	*	---	*	*	*	.	*	*	---	---	.	---	---
11919	.	.	---	*	*	*	---	***	*	3%	---	.	---	---
Basgo / Likir – stove and pottery clay														
15515	.	*	---	*	**	*	---	---	*	4%	2%.	*	---	---
11751	.	.	---	.	*	*	---	---	.	12%	---	---	12%	---
11752	.	.	---	.	**	*	---	.	*	8%	2%.	.	---	---
Likir – adobe bricks and clay pit														
11763	---	.	*	.	.	*	---	**	***	---	---	.	---	---
11921	.	.	*	.	*	*	---	*	**	---	---	---	---	---
Likir – sand														
11749	---	.	**	---	---	*	---	*	**	.	---	---	---	---

Table 3.4 Results of the clay mineral analysis.

Sample	Smectite	Vermiculite 14Å/18Å	Illite	Kaolinite	Chlorite	Mixed layer
Basgo – Maitreya Lhakhang						
8469	22	---	22	37	3	16
8479	18	---	16	52	0	14
8496	44	---	16	24	0	16
Basgo – Lotsāba Lhakhang						
8482	9	---	14	51	4	22
8483	20	---	15	44	3	19
11946	6	---	---	65	3	26
11948	28	---	---	44	2	27
Basgo – Lhakhang close to road (Highway NH1D)						
8475	24	---	9	43	3	21
11928	18	---	---	41	5	37
8499	30	---	21	29	3	16
8472	9	---	14	50	4	23
11933	9	---	---	53	7	32
Basgo – building raw material						
15410	30	---	---	32	2	36
11915	72			13	6	8
15411	38			26	0	36
8465	18	---	11	51	4	16
11952	20	---	---	47	2	31
Basgo – clay stove (<i>thab</i>)						
11748	11	---	42	10	37	0
15412	20	---	28	19	33	0
11919	38	---	19	7	36	0
Basgo / Likir – stove and pottery clay						
15515	0	---	---	31	0	69
11751	0	---	---	43	0	57
11752	0	---	---	38	0	62
Likir – adobe brick and clay pit						
11763	6	---	---	63	14	16
11921	35	---	---	49	6	10
Likir – sand						
11749	4	---	---	66	4	26

DISCUSSION

5.1 Research question 1: What are the particular properties used to categorise specific commonly used earth building materials? What are the material properties, which support a particular building material's use for the building purposes mentioned?

The examined samples are designated for specific interior and exterior use. Most common plasters are made as two-layer plasters with a lower layer (also ground or levelling layer) and an upper plaster layer. Other samples are connected to the use as adobe bricks, the construction of a flat roof, the making of pottery ware, or the creation of a stove. According to the results of this research, the local tradition of Basgo and Likir has a long history and particular types of clay and mixtures for each of these purposes. Also the single sites, where the materials were applied, vary from each other, leaving a rather complex network of different material applications. The main general features will be given in the following.

Grain size distribution

- The levelling layer of the pillar plaster in the Maitreya Lhakhang is rather fine and applied onto the pillar using organic fibres fastened around the pillar. These fibres are introduced as a layer for the compensation of different expansions of the wooden pillar and the plaster. The levelling layer for the pillar plaster is dominated by silt and sand fractions. It is rather fine, which may result in its ability to be easily pressed between the fibres. The upper layer contains a larger amount of clay. The need for adding coarse material in both layers may result in a relatively high content of swellable clay minerals. Compared to the pillar plasters, the interior plaster in the Maitreya Lhakhang shows a much higher content of gravel and less clay. The general composition, in particular concerning the content of sand and silt, is similar but coarser compared to the upper plaster layer.
- The upper layers of the interior plaster used in the Lotsāba Lhakhang are much finer than those used in the Maitreya Lhakhang. The levelling layer applied in the Lotsāba Lhakhang is more similar to the upper layer used in the Maitreya Lhakhang. Contrary to the Maitreya Lhakhang, in the Lotsāba Lhakhang there is no evidence of the addition of coarse material. For the adobe bricks, coarse material seems to have been added, and this material shows similarities to the interior plaster found in the Maitreya Lhakhang.
- The examined adobe brick from the 'Lhakhang close to the road' shows strong similarities to the adobe brick in the Lotsāba Lhakhang. Nearly all analysed data match. In the 'Lhakhang close to the road' the exterior plaster seems to be made with a similar raw material as used for the interior plaster. A close similarity in different properties between samples 8469 (pillar plaster from Maitreya Lhakhang) and 8475 (interior plaster from the 'Lhakhang close to the road') is given. The matching properties point towards the use of a rather similar raw material.
- A similar result is also stated for samples 11933 and 11928 (brick and plaster from the 'Lhakhang close to the road', respectively), leaving for sample 11933 open the changing rounding of grains being the result of an anthropogenic act via the preparation of a similar mixture, or the result of a natural process caused by geologic transport. Such slight differences also show that the basic material used within the same temple structure was not necessarily from the same clay pit. Specific evidence for this fact is that samples 8575, 8499 and 8472 – which are samples of further plasters and bricks within the 'Lhakhang close to the road' – obviously differ from sample 11933.

- Evidence for a mixing of two or more types of clay or sand is given by a bimodal grain size distribution and by the use of different grain shapes within the same building material.
- The locally available *dzasa* is rather coarse and is the basic material for further mixtures of plasters and clay used for flat roofs. The *dzasa* is mixed with *thetsa*, increasing the content of sand. The mixture of *dzasa* and *thetsa* is similar to the interior plaster in the Maitreya Lhakhang. This mixture was also applied to the roof of the Maitreya Lhakhang and to the adobe brick in the Lostāba Lhakhang. This fact points towards a commonly known use of the *dzasa* / *thetsa* mixture.
- Raw material for stoves from Basgo show a rather high content of gravel and sand and a lower content of silt and clay with an average ratio of app. 3:4:2:1 in the given order. Several materials are known in Basgo for the construction of a stove. Samples from Tunlung and Ne are similar to each other but vary strongly from the *thabsa* found along the highway. This much finer sediment from Basgo with a proportion of 0 (gravel) : 0.5 (sand) : 5.5 (silt) : 4 (clay) or 0:1:11:8 shows much more similarities to the clay from Likir, which is used for pottery and stoves. The *thabsa* from Likir has to be mixed with a specific type of sand, while the *thabsa* from Ne and Tunlung remains unmixed. Some of the clay from Likir, which is used for pottery ware, can also be used for the production of a stove.

Grain shapes

- Observed is the dominance of ‘angular-shaped’ grains with a partial tendency towards ‘beginning rounding’. This points towards a rather short distance of geologic transport.

Bulk mineralogy

- Some mineral features have strong similarities with the examined building materials. The average amount of 14Å minerals and of mica appears as traces, while 7Å minerals, quartz and K-feldspar appear in small amounts. The average content of plagioclase is medium. A few samples contain dolomite. About two thirds of the samples contain traces of hematite, which is manifested in the reddish colour of the Basgo clay. The two samples from Tunlung contain traces of goethite, giving them a yellowish colour. Gypsum was found as traces in interior plasters of the Lotsāba Lhakhang and the ‘Lhakhang close to the road’. This points towards the use of gypsum as a base layer for mural paintings in these early temples in Basgo. The content of calcite ranges between 6% and 15%, pointing towards a natural deposit of calcite in the raw material. In the samples of Tunlung, no calcite is present, and in the sample of Ne only 3% calcite was identified. This points towards its qualification as heat-resistant stove material, since the lesser amount of calcite results in higher flexural strength. On the other hand, the samples from Likir – which are known for their use in making stoves or pottery ware – do not follow these ideal properties and show a content of calcite between 4% and 12%.
- As an example, the content of amphiboles in the pottery sand of Likir (sample 11749) indicates the content of a metamorphic stone being related to the formation process of clay. Based on the existence of amphiboles, in the 2 µm CMA-graphics, a peak of app. 62°θ (app. 1.49 Å) shows a di-octahedral structure. The peak at 61°θ shows a tri-octahedral structure. These are the weathering-resistant components kaolinite, muscovite and muscovitic illite. Amphiboles weather easier and convert into smectite in a further stage (see Fig. CMA 3.27 in the Appendix of Chapter III).

Clay mineralogy

- In general, the Basgo-Likir samples show a rather high amount of swellable clay minerals (up to 72%), on average between 20% and 40% of the clay fraction. In 23 of the 26 samples swellable clay minerals are present: 23 with smectite and 14 also with vermiculite 18Å. The content of swellable clay minerals is rather high in the interior plaster of the Maitreya Lhakhang, which explains the addition of a high amount of coarse material. In the Lotsāba Lhakhang and in the 'Lhakhang close to the road', the content of swellable clay minerals is less. This explains the difference in the use of coarse material compared to the Maitreya Lhakhang.
- The CMA of the *dzasa* / *thetsa* mixture (sample 8465) shows strong similarities to the pillar plaster in the Maitreya Lhakhang (sample 8479), in particular in regard to the content of smectite, illite and chlorite. Sample 8479 was collected from a clay pit close to the Maitreya Lhakhang, and the matching results of the CMA might be an evidence for using clay from close to the temple for various applications, like making plasters or flat roofs. This fact strengthens the hypothesis that certain clay mixtures, which are considered to be technically optimised for certain applications, are by tradition used for different craft activities, be it in this specific case the use as roofing clay or as plaster clay. Both types of clay are likely to have been produced during various periods of time, the roofing plaster being a contemporary mixture and the processing of the pillar plaster probably dating back a long time. The comparison of these two materials seems to strengthen the hypothesis of traditional knowledge in a continuity in the application of technically optimised clay building techniques and in the selection of particular locally available raw materials. Comparing the grain size distribution of both samples, 8465 and 8479, we find the mixture of the two clay types being adapted to the particular technical needs. For that reason the clay used as plaster was adapted by using much less gravel, keeping the content of sand similar and raising the content of silt and clay. This result given in numbers: the median of sample 8479 is located at app. 70 µm and the 2 µm fraction ranges at around 17%. Sample 8465 is much coarser due to the addition of *thetsa* sand shown by a much higher median of app. 210 µm.
- The *thetsa*, which shows a high content of swellable clay minerals between 38% and 72%, compensates for its tendency towards cracks due to its natural high content of coarse material. The same is true for the clay from Tunlung and Ne, which is used for stove construction with an amount of swellable clay minerals between 48% and 57% in the clay fraction.
- The samples from Tunlung and Ne, which are used for making a stove, show a relatively high content of vermiculite, thus being in contrast to most of the other samples. The high content of vermiculite acts as a binder, while the high content of kaolinite is responsible for a refractory property. For the samples from Tunlung and Ne, a well-crystallised kaolinite was identified.
- In contrast, the Likir samples used for the making of pottery and stoves, and also the Basgo sample collected along the highway, are the only samples without a content of swellable clay minerals and therefore with a low content of coarse material. Besides this feature, these three samples show a content of a mixed layer corrensite marker. A secondary crystallised chlorite can also be found for samples of the 'stove and pottery group'.
- The sand, which is preferably used by the potters from Likir for mixing, also shows a 4% content of swellable clay minerals in the clay fraction.
- The content of illite is in general high and constitutes up to 66% of the clay fraction. Kaolinite is in general low and ranges on average around 5%. Only in the samples from Tunlung and Ne, which are used for the preparation of a stove, does the content range between 33% and 37%,

pointing to their qualification as stove material, since a high amount of kaolinite makes it more resistant to heat. Concerning this aspect, the samples from Likir and the sample from Basgo, which are known for their use in stove construction, do not correlate with this material quality.

- In general, the high content of chlorite of the Basgo-Likir samples indicates the metamorphic character of this material differing from smectite and mica, possibly due to a different mode of geological material transport. In relation, the stove samples from Tunlung and Ne differ from the rest of the samples in that they have no content of chlorite. Completely different to the stove samples from Tunlung and Ne are the stove and pottery samples from Likir and the sample from Basgo from along the highway, all of which show the highest content of chlorite (between 57% and 69%).

Organic additives

- The use of straw is widely common and differs not only locally but also from object to object and even within objects, particularly when an object is erected in different building phases.
- The levelling plaster (= ground plaster) used on the pillars in the Maitreya Lhakhang is reinforced by the fibres of the rope fastened around the pillars. This is why the content of additional straw fibres is kept low in this plaster. The length of fibres is found to be up to app. 3 cm. The upper layer shows an even smaller content and shorter fibres with a length of up to app. 1 cm. In this upper layer reinforcement is still required, but since the attempt seems to have been to keep the surface smooth, the tendency is to reduce the amount of fibres. The wall plaster in contrast to the pillar plaster shows fewer and smaller fibres, even in the levelling layer, which points towards chronologically different stages of preparation between wall plaster and pillar plaster.
- The upper layer in the Lotsāba Lhakhang, in contrast, shows a much higher content of straw with a length of up to 2 cm, which was coated with a thin base layer for the mural paintings without using straw but rather gypsum. In this case, the levelling layer contains a higher amount of straw than the levelling layers used for interior plaster or pillar plaster in the Maitreya Lhakhang. This also points towards the use of different methods of application. Rather unusual is the use of straw (with a length of up to 3 cm) in adobe bricks.
- For the plaster in the 'Lhakhang close to the road', the amount of fibres used is high and their length ranges up to 6 cm. For the exterior wall plaster with a rather similar mineral composition to the interior wall plaster, the fibres used are slightly shorter (up to 3 cm) but the general mixture appears similar. Contrary to the Lotsāba Lhakhang, no fibres were used for the preparation of adobe bricks.
- For recent plasters in Basgo, the *dzasa* is mixed with the sandy *thetsa*, which is a commonly known method. In this case, the levelling layer is mixed with straw and the upper layer remains without fibres. A recently prepared adobe brick (sample 11952) keeps the tradition of adding organic material to the bricks. In this case, small branches were used. Material used for the preparation of stoves remains without the addition of any organic fibres.
- Specifications for a *thabsa*:
 - In the case of the locally available *thabsa* from Likir, a mixture of 2:1 (clay:sand) is recommended by Rigzen Wangyal and his family (the potters from Likir) (Interview Rigzen Wangyal in August 2011). The laboratory test using a ratio of 6:1 (clay:sand) showed that the shrinkage during a three-day drying process was still 8% and that the content of sand needed to be increased for less shrinkage. For potters and *thab* makers, it is essential to

reduce shrinkage as much as possible during the drying process. The addition of sand fulfils this need. As the examination shows, the firing process with a maximum shrinkage of 2% is not as problematic.

- Furthermore, the quantity of water used for processing the clay influences the processability and quality of the result. Each type of clay has its own features. In the case of the clay used for stoves, a variety between 15% and 29% was determined. With the *thabsa* from Basgo (sample 15515), the highest content of water (29%) was needed in order to achieve norm-stiffness. Adding app. 15% of sand to the raw material changed the need for water to only 27%.

5.2 Research question 2: If there are any regional relations in the knowledge transfer about a particular material, in what way can they be related to specific locally conventional terms?

For the samples collected in the Basgo-Likir region, several local terms are known. This is primarily the case for raw material and less for processed objects. The mixtures themselves follow local traditions without any further conceptual classification. This makes their scientific differentiation much more difficult than is the case with raw materials, which cannot be mixed, such as wood or stone.

The terms are not only commonly known locally; *thabsa* (Tib. *thab*, “stove”; Tib. *sa*, “earth”) is a Tibetan term and is commonly known in Tibet. Its designation defines its use and by that a particular quality of clay. Until now, no data have been available on the earliest development of a traditional Tibetan stove. It is related to fixed settlements as well as to nomadic households (Interview Tsering Drongshar 2016). The stoves examined by the author were either still in use or demolished. All of them showed reliefs of auspicious Tibetan symbols on their surface. Since the beginning of this tradition, knowledge about particular properties of clay must have been given. As seen in the preceding analysis, it is difficult to determine a particular material quality of clay just by its colour. The *thabsa* samples from Ne, Tunlung, Basgo and Likir are very different in their visual and haptic appearance. A resident of Basgo drew the author’s attention to the use of the Basgo *thabsa* for making smoke pipes, since this material is heat-resistant. This information shows that technical development was not necessarily restricted to a search for particular stove material but also arose from daily life experiences in the use of heat-resistant materials.

Local traditions in using particular terminologies for clay used as building material are connected to a particular use and to sense-perceivable properties as generally standardisable technical specifications. Such standardised specifications are based on the empirical understanding of technical properties of clay. The process of assigning a particular term to a particular type of clay may strongly be shaped by its individual use, for example, by mixing, desludging, adding water or any other additives. This individual use connected with an individual perception may differ for a clay with one particular designation by showing different mineralogical properties when being dug at different sites. This fact turns the individual perception of the craftspeople into a central ability in keeping and adapting technical characteristics.

A variety in understanding properties of one specific type of clay is shown with a clay known as *dzasa*. The term *dzasa* (Tib. *rdza sa*) is known at various places in Ladakh, like Basgo, Likir or Shey (Feiglstorfer 2014: 372). In Basgo, traces of hematite in this clay are responsible for colouring the temple hill red. According to the Tibetan dictionary (www.thlib.org), various translations for *rdza* are given, such as “clay” or “earthenware” (Jim Valby), “clay-slate” (Ives Waldo) or “terracotta” (Rangjung Yeshe). When speaking about its designation as clay, according to the results of research it can be categorised as clay of a certain fineness and processability used for a range of crafts. Earthenware and terracotta are fired materials and show a terminological relation to pottery ware. According to Tsering Drongshar, who grew up in Central Tibet (correspondence in March 2016), the Tibetan term *rdza sa* simply describes a clay without any further specification. Contrarily, a clay known as *thetsa* (Tib. *'phred sa*), which in the Basgo region refers to a clay collected along the slope of a hill (Feiglstorfer 2014: 373), is not known to Tsering Drongshar.

5.3 Research question 3: In what way are building techniques and crafts related to each other and how can the gained knowledge be useful for future applications?

In vernacular architecture the use of raw materials follows an economically optimised way of processing and use. Regarding clay in the Himalayas, the raw material is part of the natural environment. Its sustainability after use is given either by its recycling into new objects made of clay or simply adding it to the soil of the surrounding environment. For recycling, it can be mixed with other mineral or organic materials to improve particular qualities. In the case of plasters, we know of the traditional reuse of sooted kitchen plaster to make flat roofs waterproof. In the case of plasters, adobe bricks, and flat earth roofs the reuse of clay at other building sites is an option with the positive side effect that this reuse may reduce the mixing effort. In the case of fired clay, such as pottery ware, the crushed objects can be again mixed with clay or reused after grinding them into powder as base material for further mixtures.

This study showed that within craft traditions the same type of clay can be used for various craft techniques. In this respect, knowledge of the making of a plaster, a clay stove, a flat roof or pottery ware is, on the one hand, connected to the single crafts and allows for the technical understanding of related craft techniques. On the other hand, it is connected to a general understanding of optimising material qualities and techniques as a general knowledge far beyond a focus on just one single craft.

This holistic approach in vernacular building techniques is also visible in the use of particular terms. *Dzasa*, for example, is used for the raw material of pottery ware, plaster and flat roofs but in each method of processing it is related to a specific technique of mixing and applying additives. The term *thabsa*, for example, is not only used for stoves; some species of *thabsa* are used for making pottery. Another example is a specific type of sand from Likir, which, due to its mineral qualities, is not only used for pottery but also for making clay stoves and for processing adobe bricks.

Due to their ecological qualities, the materials mentioned are highly sustainable, which can be a future challenge for their use beyond existing traditions. Changes of traditions are initiated when

they begin to be neglected by the local community. Clay traditions, as we find them at Basgo and Likir in Ladakh, are locally determined due to particular locally available material properties and commonly applied processing methods. They are part of the material culture of a local community. Their application to other places or societies is in most cases connected to changes or a loss of these traditions. Learning from traditions means gaining a general understanding of basic properties of materials and processing techniques, and applying this knowledge to particular new situations.

From techniques used to make a flat roof or plaster, for example, we may learn about coordinating different types of clay in several layers and about the technically optimised use of additives. However, local recipes are hardly to be transferred from one site to another without any loss but they rather have to be adapted. As far as known, the making of a clay stove in a Tibetan manner is not existent in Western traditions. In this respect, apart from its materiality its social connectivity has to be taken into account. In this regard, the complexity in the interaction of knowledge and practice according to traditional patterns of the use of materials needs to be questioned, researched and be brought into relation to particular local resources and traditions.