ELSEVIER

Palaeogeography, Palaeoclimatology, Palaeoecology 133 (1997) 103–116

PALAEO

Geomorphological processes and their palaeoenvironmental significance at the Shum Laka cave (Bamenda, western Cameroon)

J. Moeyersons *

Royal Museum of Central Africa, B-3080 Tervuren, Belgium

Received 26 February 1996; accepted 19 November 1996

Abstract

The climatic–environmental history of the Shum Laka cave (western Cameroon) and its surroundings has been established by means of geomorphological, sedimentological and botanical data, tied in a well-dated stratigraphical sequence. Since ~30,000 yr BP, this mountainous area (1,650–2,000 m ASL) has never been a desert, nor a tropical forest. Temperatures seldom significantly dropped below freezing. Mountain forest, with galleries along the water courses and grassland in between, prevailed most of the time. A certain evolution can be observed from ~31,000 to ~20,000 yr BP. Annual precipitation was initially higher than today, and subsequently somewhat lower. From 13,000 yr BP onwards, humidity and temperatures increased again. Around 9,000 yr BP they probably reached higher values than today. From 9,000 yr BP human activity became very apparent. This may have influenced the evolution of the natural landscape, and obliterated climatological effects.

This evolution has been interrupted three times by dryer climatic conditions, which each time lasted for only 1 or 2 millennia, respectively at ~33,000, at 11,000, and at ~3,000 yr BP. Another important, less humid, episode occurred between 6,070 and 3,180 yr BP. Finally, there is some evidence for a drier period between 8,480 and 7,150 yr BP. The climatic evolution, established for the Shum Laka cave, confirms and refines former data from the area and is in good agreement with data from Barombi Mbo and Chad. © 1997 Elsevier Science B.V.

Keywords: Cameroon; geomorphology; palaeoenvironment; palaeoclimate; cave

1. Introduction

The Shum Laka cave is a 20-m-deep and 50-m-wide recession within a cliff face. It lies at 5°51′37″N, 10°04′44″E, and ~15 km to the south-east of Bamenda (Fig. 1). The cave occupies a mid-slope position, at 1650 m ASL, along the inner wall of the Bafochu Mbu caldeira described by Dumort (1968).

The Laka, a small creek, forms a waterfall in front of the cave. A topographical map of the cave is presented in Fig. 2.

Archaeological excavations at the entrance of the Shum Laka cave (de Maret et al., 1987) revealed the presence of >3-m-thick sedimentary infill, dated by ^{14}C between ~31,000 yr BP and the present. Such a long and continuous sequence is rather exceptional in West Africa. The presence of archaeological remains throughout the entire stratigraphical succession makes the site even more attractive. Although pollen are absent, the nature of the deposits, the vegetational debris and the

---

* Corresponding author. Fax: 02.767.02.42.

PII S0031-0182(96)00148-4

Fig. 1. Location of the Shum Laka cave and geomorphological sketch map of the area.

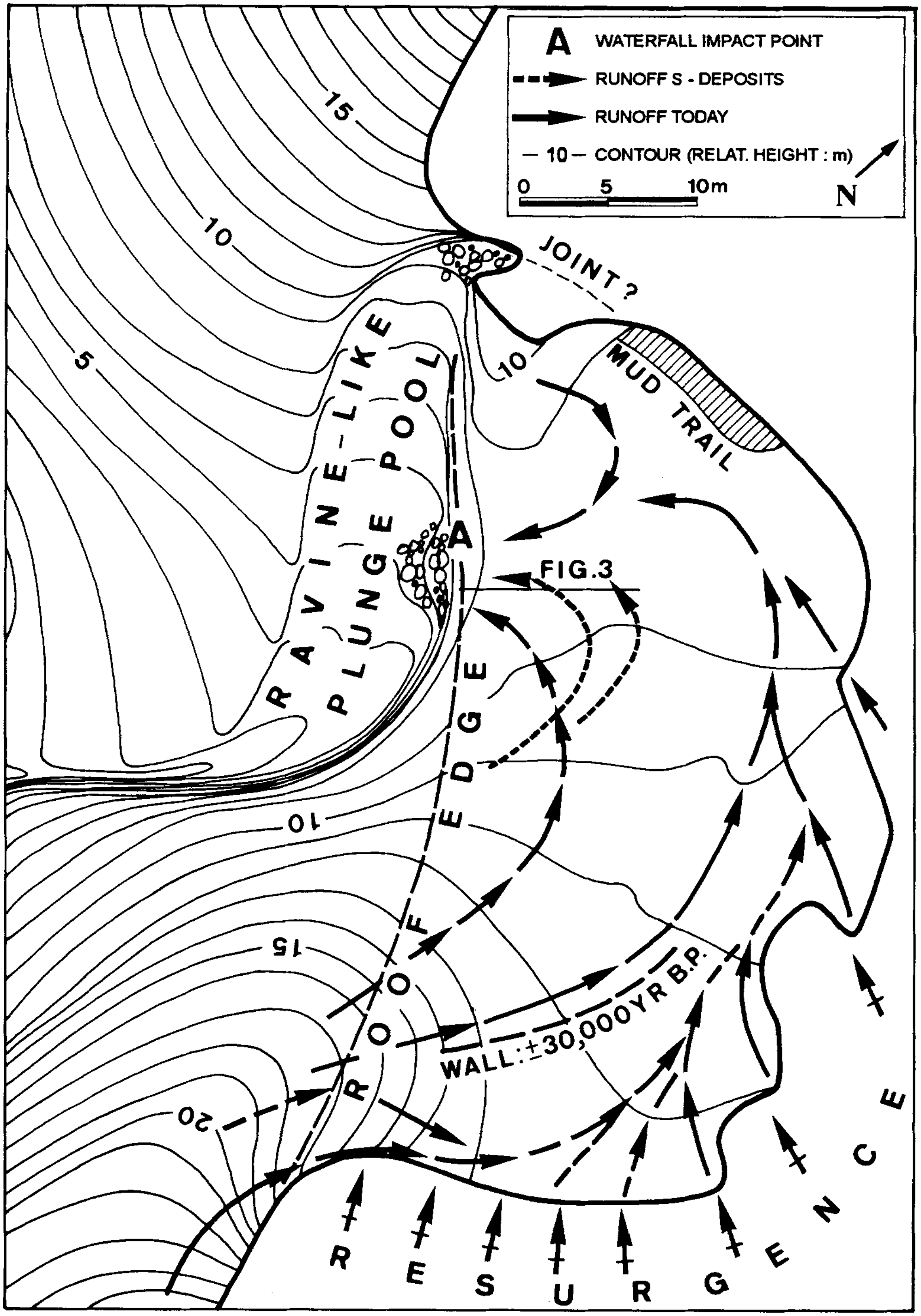

Fig. 2. Topographical map of the Shum Laka cave and "plunge pool".

geomorphology of the cave provide some interesting facts about the late Pleistocene and Holocene environmental evolution of the area.

2. The cave and its deposits

The geomorphology of the cave and the nature and stratigraphy of the deposits have been studied by Moeyersons (1996). The cliff in which the cave has been hollowed out comprises fairly massive fissured and partly weathered welded tuffs, which belong to the middle volcanic series described by Gèze (1943). Approximately 1 m above the actual floor of the cave appears the top of a much more weathered volcanic breccia.

Sporadic widening and enlargement of the cave may be related to the two ways in which water arrives in the cave. Firstly, water from the Laka valley above the cave seeps along fissures and joints through the welded tuffs and reappears on top of the breccia in the southeastern part of the eastern cave wall (Figs. 2 and 3). Desquamation and detachment of small rock flakes seem to be especially active in this resurgence area and is a factor in the widening of the cave. Secondly, runoff from outside arrives in the cave along the southeastern part of the entrance. Both resurgence and runoff water transport gravels and silts along the routes indicated in Fig. 2, and contribute to lateral scour along the interior of the cave. Some of the eroded material accumulates in form of "dust" in the lowest part of the cave towards the entrance. The archaeological excavations carried out in this area indicate that these deposits are only 5–10 cm thick. They truncate a >3-m-thick sedimentary layer, resting on the weathered bedrock of volcanic breccia. From old to young the following division is made: P-deposits, S-deposits and T-deposits (Fig. 3). A large number of ^{14}C dates supports this sequence (Table 1; Fig. 3).

2.1. *The S-deposits*

The S-deposits are the oldest dated deposits at the entrance of the cave. They are ~2 m thick and cover an ancient depression, probably an old plunge pool, extending several meters into the cave. The depression was carved out in the breccia bedrock and part of the P-deposits.

According to ^{14}C-dates Oxa-5200, Oxa-4944 and Oxa-4945 (Table 1), they represent the period between ~32,000 and ~11,000 yr BP. This material is composed of sand and loam mixed with rock debris of variable size, mainly rockfall from the roof of the cave.

The sandy-loam fraction (finer than 0.002 m) shows lamination over the entire depth of the complex. Running water has played a role in its deposition. However, the water flow seems to have been weak and more characteristic of runoff than of river flow. This can be deduced from the fact that the dip of the long axis of rockfall fragments most closely corresponds to the dip of laminae in the fines. Rock fragments, longer than 3 cm, have not been displaced by water currents after their fall and, therefore, never show an imbrication structure.

Wide and shallow runoff channels in the fines at the cave entrance suggest a pattern of conveyors (Fig. 2), comparable with the actual one, described above, but with a much stronger curvature. This confirms (Moeyersons, 1996) that, somewhat later than 30,000 yr BP, the cave was ~10 m narrower than today. The aproximate position of the southeastern wall around 30,000 yr BP is indicated (Fig. 2).

Because post-rockfall reworking of the rock debris seems negligible, the numerous discontinuous "stone-lines" represent temporary accumulation surfaces within the S-infill. Two units can be distinguished. The lower one shows vertical accretion, the basal and two lower stone-lines which reflect more or less the shape of the bottom of the ancient plunge pool. The upper unit is characterized by a stone-line, dipping outwards of the cave at 5–10°. Two secondary stone-lines start from this level and plunge steeply towards the cave outlet at an angle of 30–35°. This picture is reminiscent of deltaic fore-set deposits with lateral accretion, covered by top-set beds. The two steeply inclined stone-lines represent rather short events. The summital stone-line could be polygenic.

The change from vertical to lateral accretion has been dated by interpolation at ~20,000 yr BP and coincides with a change in rockfall intensity.

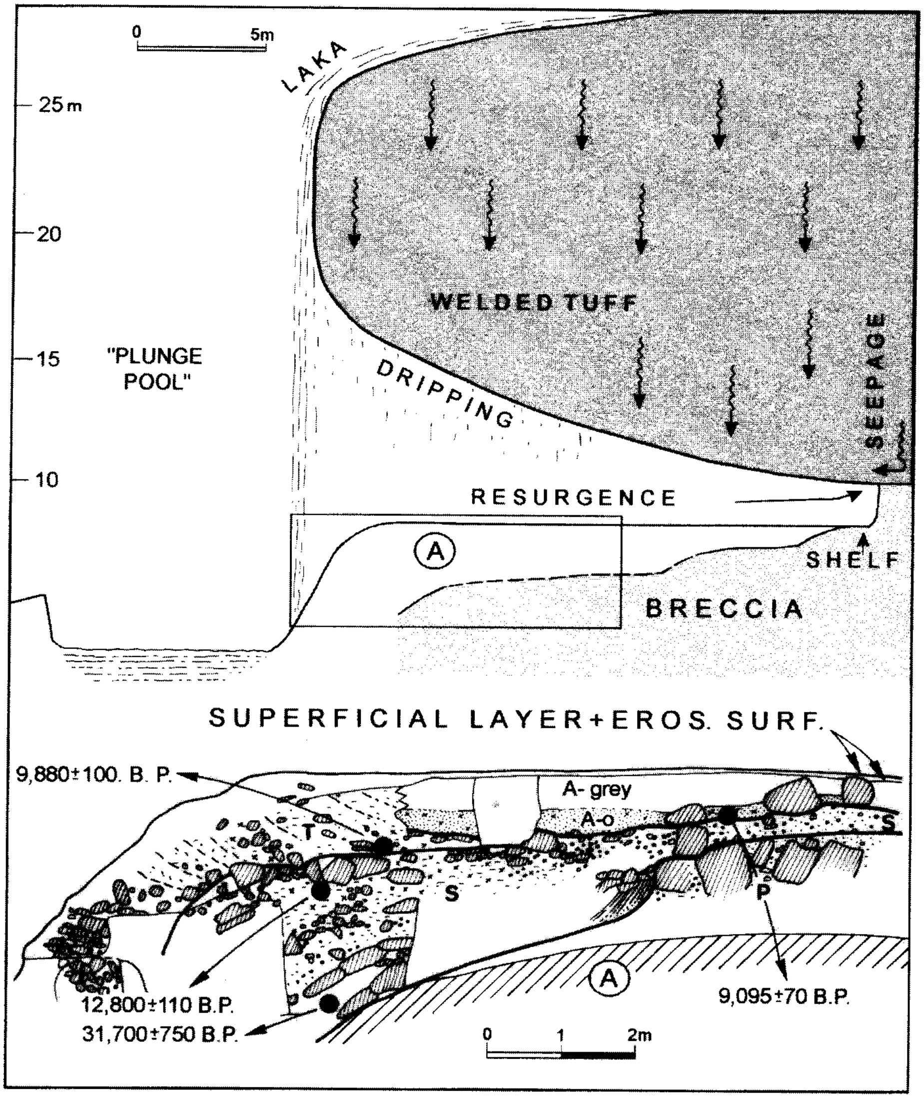

Fig. 3. Shum Laka cave: geology, water circulation and stratigraphy of the deposits at the entrance. The localization of the stratigraphical section is indicated in Fig. 2 — *A-grey* = grey ash; *A-o* = ochre ash.

Rockfall fragments are very important in number and size during the phase of vertical accretion: heavy concentrations occur shortly after the gouging of the old plunge pool and also between 30,000 and 20,000 yr BP. During the subsequent period of lateral accretion, rockfall has been much more sporadic, but an increase can be observed between 12,000 and 10,000 yr BP.

The textural and morphoscopic analysis of the <2000-μm fraction does not show significant differences between vertical and lateral accretion, nor between "stone-lines" and finer portions in the section. All samples are bimodal and poorly calibrated. Bimodality results from a mixture of coarse sand or gravel with a population of grains around the modal value of ±16 μm. In the sand fraction (2000–63 μm), all samples contain fragments of rocks from the ceiling and roof of the

Table 1
^{14}C dates from the Shum Laka cave

	Age (yr BP)
Surficial dust layer	40±40 (BM-2495) 200±60 (BETA-51835) 885±55 (Hv-10.587)
T-deposits — grey ash	1,310±65 (OxA-5201) 1,360±80 (BETA-51837) 1,690±55 (Hv-10588) 2,150±110 (BETA-51836) 2,940±60 (OxA-5207) 3,025±60 (OxA-5206) 3,045±60 (OxA-5205) 3,180±80 (BETA-51834) 3,300±90 (OxA-5204) 3,810±60 (OxA-4538)
T-deposits — ochre ash	6,070±340 (Hv-8963) 6,360±100 (BM-2496) 6,870±80 (OxA-4359) 6,980±260 (Hv-8965) 7,040±80 (OxA-1362) 7,150±70 (OxA-5203) 8,480±140 (Lv-1603) 8,540±90 (OxA-5202) 8,705±275 (Hv-8964) 9,095±70 (OxA-5636)
T-deposits — fluvial part below base of ochre ash	9,880±100 (OxA-5635)
S-deposits	12,800±110 (Oxa-5200) 30,300±1,600 (OxA-4944) 31,700±750 (OxA-4945)
P-deposits	no dates

cave. Welded tuffs are sub-rounded and hollowed out, reflecting chemical alteration. Individual quartz grains, some feldspar crystals and a rare altered mica, probably phenocrysts from the cave rock, are also present. Allochthonous elements could not be identified. Wind-blown material is therefore absent.

The silt population (63–2 μm) has been tested in the 32-μm fraction. Its composition is very different from the sand fraction. Apart from a few quartz grains, some feldspar, a sanidine and some pumice, the bulk of the population contains glass shards and saccharoid structures, cemented by iron oxide. In fact, we see here the disintegration of the ignimbritic rock into its formerly welded constituents. This type of weathering of massive rocks with only a minor production of clays has been studied for a long time and corresponds with the sandy deep weathering type of Bakker (1967). This weathering type is generally associated with a subtropical climate, whereby the circulation of iron colloids in the rocks is responsible for their desquamation along shells and their further breakdown into their granular constituents (Schnütgen, 1983, 1992).

2.2. *The T-deposits and corresponding ash layers*

The T-deposits rest unconformably against and on the S-deposits and dip towards the inside of the cave (Fig. 3). They are believed to be the fluvial infill of a rejuvenated plunge pool (10,000 yr BP). The T-deposits in the bottom of this plunge pool contain large boulders and rocky material, with a clast supported to open space structure. They indicate important mass wasting in the Laka valley above the cave. The overflow material in the cave is dated at its base as 9,880±100 yr BP (date OxA-5635; Table 1 and Fig. 3). It consists of structureless gravelly loamy sands with occasional concentrations of rounded to subrounded pebbles and small boulders. This deposit dips slightly towards the inside of the cave. It is impossible to say to what degree rockfall from the roof is mixed in with outside material. However, the general trend of fining upwards, so typical of many river deposits, is evident.

The overflow material changes laterally into two superposed anthropogenic ash layers into in the cave (Fig. 3).

The lower ochre ash occupies only the central and deepest part of the cave, where it is ~50 cm thick. The typical ochre colour is due to the presence of fragments of burnt earth in all fractions. White to grey ash lenses occur occasionally. Anthropogenic reworking is evident in many places. Human skulls, stones and small boulders, from the underlying rockfall, are present. The grey ash rests either directly upon the ochre ash or is separated from the latter by a zone of alternating ochre and grey or whitish laminae, which indicates sporadic runoff.

The T-deposits and related ash layers differ from the underlying S-deposits in several aspects. Firstly, boulders and coarse material are almost absent in the T-deposits and especially in the ashes. Rockfall from the roof, common during the late Pleistocene, came suddenly to an end. Secondly, traces of fire are much more numerous than in the underlying S-deposits. Apart from the two ash layers, many rolled fragments of burnt earth occur in the T-deposits.

There are strong affinities between the textural composition of the mineralogical components of the grey ash, the ochre ash and the S-deposits. The bimodal trend and poor calibration are typical for the S-deposits.

Because of the apparent anthropogenic disturbance of both the ochre and grey ash layers, it was thought inappropriate to make detailed subdivisions of these layers on pure stratigraphical grounds. In the present case, it was of great archaeological interest to date as many cultural remains (e.g., burials, hearths) as possible. Twenty ^{14}C dates (Table 1) were obtained from both ash layers. In the ochre ash, they cluster around 7,000 yr BP and range between 9,100 and 8,500 yr BP. The hiatus between 6,000 and 4,000 yr BP corresponds to the interval with laminae between both ash layers. In the grey ash, human activities center around 3,000 yr BP and isolated events date between 2,000 yr BP and the present. A hiatus covers nearly the entire third millennium BP.

2.3. An erosion surface and the superficial layer

The surficial layer, described above, truncates the T-deposits and, deeper into the cave, also the updoming S-deposits, before wedging out against the backwall of the cave. The top of the deposits is extended by a platform or shelf in the bedrock (Fig. 3). In spite of the large number of ^{14}C dates, this erosion surface, which separates the superficial layer from the older deposits is difficult to date. According to date Hv-1O.587 (Table 1), the erosion ended less than a thousand years ago.

3. Environmental evidence from the S-deposits

3.1. Evidence from fine-grained sediments and floral remains

As mentioned above, <63-μm fines may indicate subtropical weathering conditions. Furthermore, the fines in the S-deposits have been transported by runoff. Part of this wash came from outside the cave. Of course, runoff is not a climate indicator, as this process occurs in deserts as well as in tropical regions. However, it does point to the inability of the vegetation of that time to protect the soil and/or to the existence of open patches of ground.

On the other hand, the presence of vegetation is apparent because of the high organic content (up to 8% and more than 8% of the total weight) of the fines. Moreover, charcoal fragments are scattered throughout the entire sequence. Surprisingly, the determinations did not reveal the presence of many woody plants other than *Protea mad.* sp. The ecological conditions of this species (Beard, 1992), imported or left behind either by man or by natural processes, suggests the idea that the surroundings of the site during this time were never really arid like a desert, nor were they extremely hot and humid like a tropical forest. Temperatures never dropped significantly below zero for several days. A few charcoal fragments of *Kigelia* cf. *africana*, *Drypetes* sp., *Triumphetta* sp. and *Hypericum* sp. point to a montane forest with open patches and gallery forest. The species found in the charcoal are still present today.

3.2. Indirect evidence from the rockfall

Rockfall inside the cave may have some palaeoenvironmental significance. Rockfall caused by freezing has to be rejected for two reasons. Firstly, frost wedges or cryoturbation are absent in the deposits. Secondly, *Protea mad.* sp. seems unlikely to survive temperature drops below 0°C. Also the hypothesis of earthquake induced rockfall is not likely at Shum Laka. According to information from the local inhabitants, the region actually suffers rather heavy earthquakes at regular intervals, accompanied by the fall of debris from steep slopes. But inside the cave, no traces of important rockfalls are visible for the period of the last 9,000 years.

It seems therefore appropriate to attribute rockfall to seepage of water through the roof of the cave, a combination of weathering and hydrostatic pressure contributing to the opening of existing joints and massive exfoliation. The occurrence of seepage during the periods of rockfall is further attested to by pitting (Watson and Pye, 1985) of the upper facies of rock debris and boulders buried in the deposits. Many blocks are still in their original position, and were not water deposited.

Presently, the site of Shum Laka does not provide conclusive evidence for the interpretation of the reduced rockfall between 20,000 and 12,000 yr BP. However, a decrease in seepage, reflecting somewhat drier conditions in the Laka valley above the cave, seems a plausible explanation.

3.3. *Estimation of seepage rates by application of the* Es-*model*

The model of erosional susceptibility, Es, elaborated by De Ploey (1990), allows an estimation of seepage discharge during the deposition of the S-deposits. As seepage discharge may be related to precipitation, it could be useful to compare past with actual discharge rates. Detailed information about the application of the Es model can be found in De Ploey (1990), and De Ploey et al. (1995). Application of the Es model at Shum Laka may explain why the southeastern wall receded ~4 m during the deposition of the S-deposits (Moeyersons, 1996). Water, seeping out of this wall, contributed to the removal of rock which accumulated in the form of disintegrated fines. Erosion consists of rill and interrill erosion, provoked by resurgent water along the wall with splash effect during the extreme events. For rill and interrill erosion, the erosional susceptibility is in the order of 10^{-3} s^2/m^2, and is given by the following equation (De Ploey et al., 1995):

$$\mathrm{Es} = V/A \cdot P \cdot g \cdot h \tag{1}$$

where Es = erosional susceptibility (10^{-3} s^2/m^2); V = total volume (m^3) eroded within a surface area A (as the wall is ~20 m long, ~5 m high and receded over ~4 m, the eroded volume is of the order of 400 m^3); A = planimetric surface (m^2) of the considered area, representing a hydrological unit (it consist here of a zone, maybe 1 m wide and as long as the wall); P = total volume of water, precipitated per m^2 during the period considered (in this case, it concerns resurgence water per m^2, of an unknown volume; the product $A \cdot P$ represents the total volume of water which percolated along the southeastern wall during a period of 20,000 years); g = gravitational acceleration (10 m/s^2); and h = loss of head in m, here represented by the rill depth, which has been estimated at 0.1 m.

Applying these values to Eq. (1) gives:

$$A \cdot P\ (20{,}000\ \text{years}) = \frac{400\ \mathrm{m}^3}{(10^{-3}\ \mathrm{s}^2/\mathrm{m}^2) \cdot (10\ \mathrm{m/s}^2) \cdot (10^{-1}\mathrm{m})}$$

$$A \cdot P\ (\text{annual}) = 20\ \mathrm{m}^3\ \text{resurgence water} \tag{2}$$

According to our measurements and estimations during the dry season in 1991/1992 and 1994, annual seepage along the southeastern wall should be slightly over 18 m^3. The agreement of this result with Eq. (2) leads to the conclusion that percolation through the roof of the cave between 30,000 and 10,000 yr BP did not differ very much from the present. Late Pleistocene conditions, such as infiltration, are much alike those of today (Fig. 4).

4. Early Holocene and Holocene phenomena in and around the cave

4.1. *Indications for reduced seepage but occasional runoff in the cave*

Rockfall material in the S-deposits contains many large boulders and even massive exfoliation plates, sometimes over 0.5 m thick. However, the actual morphology of the cave roof does not correspond to any of these detached blocks. Instead, roof and walls are smooth and weathered. This weathering zone, in some places at least 50 cm thick, consists of 1-mm to >1-cm-thick lamellae. The actual process of rock disintegration consists of exfoliation of these shells and spalls. This zone has the physical appearance of so-called spheroidal weathering (Schnütgen, 1992). Exfoliation affects even the highest parts of the roof. This is therefore not a subsurface weathering phenomenon, but the result of subaerial decay of the bedrock in the cave. This change in weathering pattern since the deposition of the S-deposits could point to reduced infiltration and seepage along joints in the bedrock, resulting in the discontinuation of the production of large rocks and boulders.

An important reduction of coarse material has been mentioned in the T-deposits from prior to Oxa-5635 (Fig. 3; Table 1), which provided an age of 9,880±110 yr BP. Rockfall and seepage appears to have been much less important than before this date.

The cave was not always dry. Frequent lamination in both the ochre and the grey ashes indicates runoff. The transitional period between both ash layers is characterized by a number of major runoff events.

4.2. *Flowing rivers*

Until ~11,000 yr BP the lowest part of the entrance formed the exit for the S-deposits. At 9,800 yr BP this situation had radically changed. The T-deposits, resting on the S-deposits, dip slightly inwards (Fig. 3) and block the exit. Perhaps there was a long standing body of water inside the cave. The permeability of the S- and underlying P-deposits kept the cave more or less dry.

The T-deposits are interesting from a palaeoenvironmental point of view. For more than 20,000 years, there is no evidence for deposition by the Laka river. The filling in of the ~32,000-year-old plunge pool was by gradual colluviation (S-deposits). The new plunge pool (10,500 yr BP) has been filled in by fluvial material from the Laka river. The Laka was apparently flowing during the deposition of the T-deposits. The conditions during which the T-deposits were deposited were at least as humid as the period before. The rate of infill was very high at the start. At 9,880 yr BP, the first fluvial deposits already flowed over into the cave.

4.3. *Vegetation*

The decrease in percolation through the cave roof since ~9,000 yr BP is difficult to interpret in terms of changes of the environment outside the cave. It could indicate reduced precipitation, but this would contradict the presence of the T-deposits. Therefore, an increase in evapotranspiration, due to higher temperatures and vegetation density, is held responsible for a reduction in infiltration. The vegetational macroremains, found in the cave, become more diversified. Throughout both ash layers *Protea mad.* sp. is present but in the ochre ashes *Hypericum* and also *Maythenus acuminatus* occur. In the grey ashes, *Protea mad.* sp. is accompanied by *Syzygium* cf. *guineensis*, *Nsete Gilettii*, *Canarium schweinfurthii*, *Raphia* sp. and *Elaeis guineensis*. *Zingiberacea* occurs in the upper level of the grey ash. This association is completed by the abundant presence, throughout the grey ash, of grass phytoliths. Faunal remains all belong to rain forest species. It is not clear to what extent plant and animal remains have been imported by man. However, during the Holocene savannah and forest were both present in the vicinity of the site.

4.4. *Human activities*

Below the level dated at 9,880 yr BP (Fig. 3), the T-deposits contain many rolled fragments of burnt earth in the coarse sand fraction. This material originated above the cave, and it is therefore likely that bush fires were frequent. The abundance of burnt earth fragments throughout the T-deposits suggests the continuation of these activities until recent times. It is possible that these activities were the direct cause for the accelerated erosion in the Laka valley above the cave. Moreover, firing activities were not restricted to the open air. Starting ~9,000 yr BP, the T-deposits laterally become two superposed ash layers, as mentioned earlier. They occupy the deepest part of the cave floor, and contain human skeletons, artefacts, ceramics, faunal and floral remains.

At first, it was thought that the considerable volume of grey ash indicated important forest clearing in the vicinity of the cave. A simple calculation, however, shows that this was not the case. The conservative estimate is that the volume of grey ash equals ~100 m^3. Fire ash of wood represents ~0.5% of the original volume (Wise, 1952). Therefore, 100 m^3 of ashes represent 20,000 m^3 of wood. This is the approximate volumetric equivalent of 100,000 small *protea* trees. Supposing an occupation time of ~1,000 years (see below), the grey ash layer results from the annual burning of 100 small trees at the most! Over a thousand years, repercussions would have been felt if tree cutting was restricted to a small area around the cave. The T-deposits indicate contemporaneous burning of wood outside the cave. It is clear that human impact on the environment was already visible in the early or middle Holocene.

4.5. Post grey ash evolution of the cave

In subrecent times, the cave underwent an important change. Sudden lateral extension of the cave is indicated by an erosion surface, which truncates the grey ash and forms the top of a bedrock platform. This platform is ~0.5 m wide along the northeastern wall, but several meters in the southeastern part of the cave. It has been suggested (Moeyersons, 1996) that desquamation, in combination with resurgence of seepage water in the walls, was the primary cause for this widening of the cave. An Es analysis for this period arrived at quantities of percolation water several orders of magnitude greater than during the deposition of the S-deposits. Only torrential conditions in the cave can explain the sudden erosion. Perhaps this involved important inflow from outside the cave along a trajectory following the walls as illustrated (Fig. 2). This flow may have caused lateral scour and contributed to the transport of gravelly rock debris. Thus cave widening indicates a sudden influx of water into the cave. This is corroborated by the presence, along the northern wall (Fig. 2), of a mud trail, coming from behind the collapsed blocks at the northwestern part of the entrance. An unidentified but important seep, possibly along a joint in the bedrock, was probably active during that time. Finally, there is evidence for a major waterfall during the same period which scoured out the plunge pool in front of the cave. It appears (Fig. 2) that the plunge pool has the outline of a wide, 2-m-deep gully, much larger in size than required for the actual discharge of the Laka waterfall. Moreover, the gully head does not end at the actual impact point of the Laka waterfall in front of the cave, but beside the entrance, approximately there where the mud trail, mentioned above, should start behind the loosened blocks. The escarpment above the gully head shows an irregular subvertical joint, partly widened by running water. The rock overhang where the Laka flows today is not affected at all.

It is obvious that during a subrecent period the Laka has had exceptional discharge rates. Seepage water entering the cave caused appreciable erosion. As yet, this sudden phenomenon remains unexplained. A sudden climatic oscillation, or an anthropogenic impact may have been the cause.

In spite of the many ^{14}C dates available, it is not easy to define the hiatus between the grey ash and the so-called surficial layer. The reason is the mixing of charcoal from the surficial layer with charcoal from the grey ash. The conclusion is that the maximum age of the surficial layer could be 885 ± 55 yr BP. The youngest uncontaminated date for the grey ash is $2{,}940 \pm 60$ yr BP. (This gives a grey ash occupation time of ~1,000 years.)

4.6. Cave dynamics today

The erosion phase, which probably started ~3,000 yr BP, came to an end with the beginning of the accumulation of the surficial layer less than 1,000 years ago. Desquamation still affects the cave ceiling today and contributes to the further development of the thin surficial layer. Seepage through the roof and resurgence of seepage water along the walls reflect alternating rhythm of dry and wet seasons. Occasional runoff redistributes the quickly disintegrating fallen desquamation shells evenly over the lower central part of the cave. It forms a 5-cm-thick veneer, mixed with ashes. At the entrance, this layer becomes more than 50 cm thick upon the ravine wall to the side of the cave. However, the Laka flow appears to have stabilized and lacks the torrential discharge rates responsible for the development of the gully-like plunge pool. The present small waterfall does not erode the wall of the ravine wall. Instead, the water is often dispersed by the wind and the load of fines it carries is retained on this wall by the present-day vegetation.

5. Climatic implications

5.1. *The period before ~10,000 yr BP*

Evidence of a different nature shows that the surroundings of the Shum Laka cave during the deposition of S-deposits experienced climatic–edaphic conditions comparable to the present day. The area was neither dry like a desert nor hot and humid like a tropical forest. The precipitation was not very different from the present day. Somewhat higher from 32,000 yr BP until ~20,000 yr BP, and somewhat lower after that. The renewed rockfall from ~12,000 yr BP indicates the onset of more humid conditions, announcing the Holocene. Temperatures never dropped significantly below zero. There was a mountain forest, probably with open patches and dense galleries along the rivers. This corroborates the findings of Kadomura and Kiyonaga (1994) in a boring along the Matongwe river, at only 4 km from the cave, but more than 300 m lower in the valley.

The close resemblance between climatic conditions of 10–30 millennia ago and the present conditions was rather unexpected. It is generally believed that arid conditions during that period not only prevailed in the Sahara but extended much farther south, even to the equator (Servant and Servant-Vildary, 1980). The findings in the Shum Laka cave strongly suggest that the area was not much affected by this arid period. A comparison can be made with Lake Barombi Mbo, ~150 km to the south, where since 24,000 yr BP the rain forest persisted with limited variations (Giresse et al., 1991, 1994).

5.2. *Climatic evolution since 10,000 yr BP*

Important changes in cave evolution occur since 10,000 yr BP. Increased river activity combines with "spheroidal weathering" and subsequent spalling and flaking. Rockfall from the roof in the form of large boulders discontinues. These changes indicate that the environment became (slightly) more humid, but with much higher evapotranspiration rates, and possibly higher temperatures, than before. However, the macrofloral remains indicate that both forest and savannah remained present in the proximity of the cave.

This period also shows an increase in human activity. Traces of bush fires are nearly 10,000 years old.

A problem is the absence of dates during certain periods (Table 1). This could reflect lack of human passage or activities in the cave. The ochre ash shows a hiatus between 8,480 and 7,150 yr BP. Another occurs situated between both ash layers and covers the period from 6,070 to 3,810 yr BP. The latter corresponds with the drier transition period between the ochre and grey ashes. Is it a coincidence that the first corresponds with a period, labelled as more arid in the Lake Chad area (Servant and Servant-Vildary, 1980)?

As mentioned above, stratigraphical as well as other evidence indicate that the cave has been flooded around 3,000 yr BP by the Laka stream and/or by runoff and seepage. Apparently, river discharge as well as precipitation became very irregular with peaks not any more attained today. This period appears to correlate with to the climatic deterioration found in the area and elsewhere by authors such as Morin (1989), Maley (1992) and Schwartz (1992), and to the period of forest degradation described by Kadomura and Kiyonaga (1994).

5.3. *A note on the significance of plunge pool development*

The stratigraphical sequence at Shum Laka has been interrupted at least three times by the development of a plunge pool in front of the cave. The oldest known pool has been scoured out around 32,000 yr BP. Rejuvenation took place at

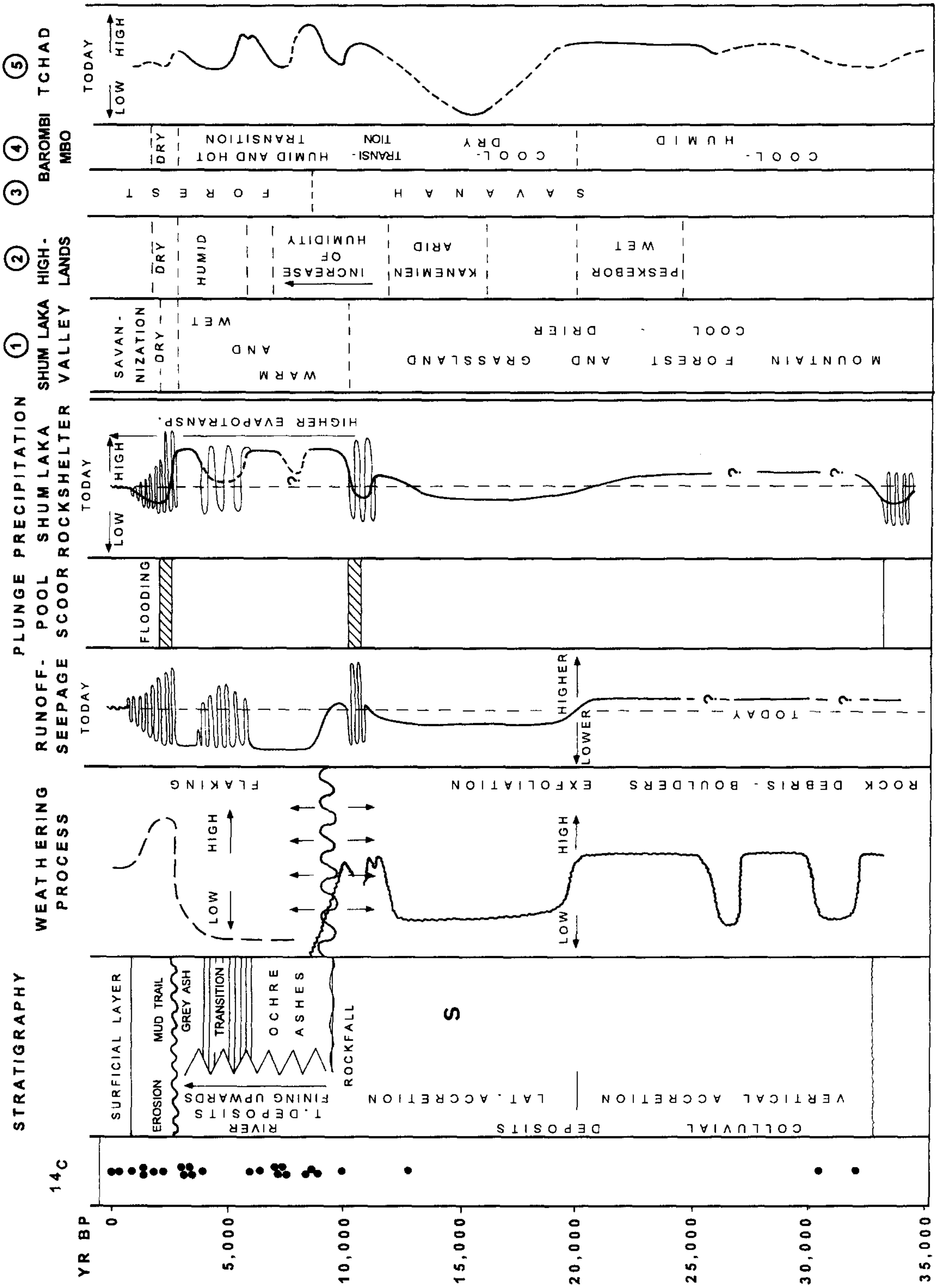

Fig. 4. Geomorphological processes and their palaeoenvironmental significance at the Shum Laka Rock cave. Comparison with: *1* = Kadomura and Kiyonaga (1994); *2* = Morin (1989); *3* = Hori (1984); *4* = Giresse et al. (1994); *5* = Servant and Servant-Vildary (1980).

~11,000 yr BP and somewhat later than 3,000 yr BP. It is amazing to note that, at least in the latter two cases, plunge pool formation took only a thousand years — two very short events during a long history. For a small stream like the Laka, plunge pool formation appears to be an exceptional event with conditions, very different from those of today. The present-day discharge of the Laka, in the order of 0.5 dm^3/s, does not result in erosion but in deposition on the edge of the ravine. Therefore, the scouring out of a plunge pool was to be related to high, possibly intermittent, discharges as for example during and after very heavy rains. Such irregular precipitation is more typical for drier areas with a reduced vegetation cover, like the Sahel, than for the more tropical regions. It is therefore tentatively proposed that periods of plunge pool development could coincide with Sahelian conditions. In this respect, the plunge pool at 11,000 yr BP may correspond to a short climatic deterioration, probably the equivalent of the Younger Dryas (Kadomura, 1994), while the plunge pool at ~32,000 yr BP appears to be contemporaneous with a climatic deterioration, also observed in Chad (Servant, 1973).

6. Conclusions

The evolution of the Shum Laka cave is partly governed by seepage and water flow from the catchment basin of the Laka. The environmental and climatic conclusions (Fig. 4) are the reflection of local conditions upstream of the cave. The catchment basin of the Laka does not drain the highlands above 2.000 m but part of a topographical surface at 1.650 m (Fig. 1). This is probably the reason why we did not find evidence for periods of frost as mentioned by Morin (1989). The elevation of the site at 1,650 m ASL keeps it far from the reach of the moist and hot equatorial forest. Finally, the western exposure of the escarpment may have increased local precipitation, as a result of which it remained humid during dry periods in the past.

The topography may partly explain why the environmental data show a certain continuity over the last 33,000 years. During this entire period, the vicinity of the cave was never as dry as a desert nor as hot and humid as an equatorial forest. Temperatures never dropped significantly below zero.

However, within these limits, climatic and environmental variations appear (Fig. 4). Generally, there is a good correlation with data from Lake Barombi Mbo, 150 km south of Shum Laka, especially for the late Pleistocene period. The more southerly position of Barombi Mbo could explain why the Younger Dryas and Holocene less humid oscillations have not been recorded there. On the other hand, the dry and humid peaks, proposed by Morin (1989), have their less pronounced counterparts at the Shum Laka Rock cave. Parallel tendencies are particularly obvious for the late Pleistocene period. Furthermore, the Shum Laka cave data complete and detail the climatic evolution of the area, established by Hori (1984) and later by Kadomura and Kiyonaga (1994). Special attention should be paid to the correlation of the climatic data from the Shum Laka cave with those from the Chad region, 500 km to the north. There is a tendency for the Holocene humid oscillations in Chad to culminate near the end of the equivalent humid periods at Shum Laka. Apparently, past humid pulsations were felt some hundreds of years later in Chad than at Shum Laka. On the other hand, the repeated dry incursions to the south took place in a much shorter period of time. Further accurate dating is required to confirm this possibly interesting detail, which may reflect either long-term air circulation dynamics or the time required by the vegetation to be restored after drought or both.

Acknowledgements

This study is part of an archaeological research project at Shum Laka (Bamenda, western Cameroon), in collaboration with the University of Yaounde (Cameroon), the *Université Libre de Bruxelles* (Belgium) and the Royal Museum of Central Africa of Tervuren (Belgium). The project was financed by these institutions and with funds from the *Loterie Nationale* (Belgium), the *Fonds National de la Recherche Scientifique* (Belgium), the *Nationaal Fonds voor Wetenschappelijk Onderzoek* (Belgium) and the L.S.B. Leakey Foundation (U.S.A.). Determinations of floral and faunal macroremains have been carried out by H. Doutrelepont and W. Van Neer. The drawings were executed by Y. Baele. We thank J. Maley and P. Giresse for useful discussions in the field and J. Maley for his pollen analysis. Additional assistance was provided by H. Beeckman.

References

Bakker, J.P., 1967. Weathering of granites in different climates, particularly in Europe. In: L'évolution des versants. Congr. Colloq., Univ. de Liège 40, 51–68.

Beard, J.S., 1992. The *Proteas* of Tropical Africa. Kangaroo Press, Hong Kong, book 144, 112 pp.

de Maret, P., Clist, B., Van Neer, W., 1987. Résultats des premières fouilles dans les abris de Shum Laka et d'Abéké au Nord-Ouest du Caméroun. Anthropologie 91, 559–584.

De Ploey, J., 1990. Modelling the erosional susceptibility of catchments in terms of energy. Catena, 17: 175–183.

De Ploey, J., Moeyersons, J., Goossens, D., 1995. The De Ploey erosional susceptibility model for catchments, Es. Catena 25, 269–314.

Dumort, J.C., 1968. Notice explicative sur la feuille Douala-Ouest. République Fédérale du Caméroun: Carte géologique de reconnaissance à l'échelle du 1/500.000.

Gèze, B., 1943. Géographie physique et géologie du Cameroun occidental. Mém. Inst. Hist. Nat., Paris, 17, 273 pp.

Giresse, P., Maley, J., Kelts, K., 1991. Sedimentation and palaeoenvironment in crater lake Barombi Mbo, Cameroon, during the last 25,000 years. Sediment. Geol., 71: 151–175.

Giresse, P., Maley, J., Brenac, P., 1994. Late Quaternary palaeoenvironments in the Lake Barombi Mbo (West Cameroon) deduced from pollen and carbon isotopes of organic matter. Palaeogeogr., Palaeoclimatol., Palaeoecol., 107, 65–78.

Hori, N., 1984. Formation and chronology of superficial deposits in the forested Southern Cameroon. In: Kadomora, H. (Ed.), Geomorphology and Environmental Changes in the Forest and Savannah Cameroun. Preliminary Report of the Tropical African Geomorphology and Late-Quaternary Palaeo-environments Research Project 980/1981, Sapporo, pp. 13–27.

Kadomura, H., 1994. Climatic changes, droughts, desertification and land degradation in the Sudano-Sahelian region – A historico-geographical perspective. In: Kadomura, H. (Ed.), Savannisation Processes in Tropical Africa, II. Dep. Geogr., Tokyo Metropol. Univ., Tokyo, pp. 203–228.

Kadomura, H. and Kiyonaga, J., 1994. Origin of grassfields landscapes in the West Cameroon highlands. In: Kadomura, H. (Ed.), Savannisation Processes in Tropical Africa, II. Dep. Geogr., Tokyo Metropol. Univ., Tokyo, pp. 47–85.

Maley, J., 1992. Mise en évidence d'une péjoration climatique entre ca. 2500 et 2000 ans BP en Afrique tropicale humide. Bull. Soc. Géol. Fr. 163, 363–365.

Moeyersons, J., 1996. Rock shelter collapse as a possible reason for waterfall retreat in the Bafochu Mbu caldeira, western Cameroon. Z. Geomorphol. N.F., Suppl.-Bd. 103, 354–358.

Morin, S., 1989. Hautes terres et bassins de l'Ouest Caméroun. Rev. Géogr. Cameroun 8 (2), 81–92.

Schnütgen, A., 1983. Micromorphologische Sprengung von Quartzkörnern durch Eisenverbindungen in tropische Böden. Z. Geomorphol. N.F., Suppl.-Bd. 48, 17–34.

Schnütgen, A., 1992. Spheroidal weathering, granular desintegration and loamification of compact rock under different climatic conditions. Z. Geomorphol. N.F., Suppl.-Bd. 91, 79–94.

Schwartz, D., 1992. Assèchement climatique vers 3000 B.P. et expansion Bantu en Afrique centrale atlantique: quelques réflexions. Bull. Soc. Géol. Fr. 163, 353–361.

Servant, M., 1973. Séquences continentales et variations climatiques: évolution du bassin du Tchad au Cénozoique superieur. Doctorat d'État, Université Pierre et Marie Curie, Paris, 368 pp.

Servant, M., Servant-Vildary, S., 1980. L'environnement Quaternaire du bassin du Tchad. In: Williams, A.J., Faures, H. (Eds.), The Sahara and the Nile. Balkema, Rotterdam, pp. 133–162.

Watson, A., Pye, K., 1985. Pseudokarstic microrelief and other weathering features on the Mswati granite (Swaziland). Z. Geomorphol. N.F. 29, 285–300.

Wise, L.E., 1952. Miscellaneous extraneous components of wood. In: Wise, L.E., Jahn, E.C. (Eds.), Wood Chemistry. Reinhold, New York, NY, pp. 638–660.