

GEOMORPHOLOGICAL DEPRESSIONS (BAS-FONDS)
AND PRESENT-DAY EROSION PROCESSES ON THE PLANATION SURFACE
OF CENTRAL-TOGO/WESTAFRICA^{*)}

With 5 figures, 1 table and 6 photos

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Zusammenfassung: Geomorphologische Depressionen (Bas-fonds) und rezente Erosionsprozesse im Rumpfflächenrelief Zentral-Togos, Westafrika

In der Zentralregion Togos (0°20'–1°37'E, 7°54'–9°18'N, 1100–1500 mm jährlicher Niederschlag) werden mit Hilfe von Luftbildern zahlreiche vielgestaltige, saisonal feuchte und überflutete, meist grasbestandene, offene und geschlossene Niederungen (franz. Bas-fonds) kartiert und im Gelände untersucht. Die Bas-fonds sind mehrheitlich in die mit Lateritkrusten überzogenen Abschnitte einer welligen Rumpffläche des präkambrischen Granit-Gneis-Sockels eingelagert. Bas-fonds beeinflussen und steuern die Prozesse der Morphodynamik auf Rumpfflächen. Erodierendes Oberflächenmaterial wird in ihnen akkumuliert; die Einschneidung des Gewässernetzes schreitet gegenwärtig voran. Nach der Lage zum Vorfluter (Ober-, Mittel-, Unterlauf) sind sieben Bas-fond Typen (A–G) zu unterscheiden. Morphogenetisch sind Bas-fonds des Typs A bis D das Ergebnis einer wahrscheinlich vorzeitlichen Prozeßkombination von subterranean Abtragung (Piping) im Verwitterungsmantel und im Saprolith und oberflächlicher Hang- und Flächenspülung. Die denudativen Abtragungsprozesse formen und modifizieren die Depressionen, deren Grundstruktur vermutlich im Grundgebirge angelegt ist. Bas-fonds vom Typ E bis G sind jüngere bis rezente Bildungen im Bereich der Akkumulations- und Sedimentationsräume (Terrassen, Auen, Sümpfe) von Flüssen und Gerinnen.

Résumé: Dépressions géomorphologiques (bas-fonds) et les processus d'érosion récente sur la pénéplaine du Togo Centrale/Afrique de l'Ouest

Dans la Région Centrale du Togo (0°20'–1°37'E, 7°54'–9°18'N, précipitation annuelle: 1100–1500 mm) on reconnaît par des photos aériennes des formes diverses des dépressions ouvertes et closes (= bas-fonds) qui sont saisonnellement humides et inondées, souvent couvertes par des herbes; ces formes sont cartographiées et analysées sur place. La plupart des bas-fonds est insérée dans la partie de la surface d'aplanissement ondulée qui est couverte par les cuirasses ferrugineuses sur le socle granito-gneissique du précambrien. Les bas-fonds influencent et règlent le processus de l'érosion sur les surfaces des aplanissements. D'après la position vers le drainage (cours supérieur, cours moyen, cours inférieur) sept types des bas-fonds (A–G) sont à distinguer. Par la genèse les bas-fonds du type A–D sont

les résultats d'une combinaison probable du processus prétemporal de l'érosion subterraine (Piping) dans le saprolith de la pénéplaine et de l'érosion superficielle des versants et l'érosion sur nappe. Les processus de dénudation modifient et forment les dépressions qui probablement ont existés avant dans la structure de la roche-mère; par l'érosion sur nappe elles sont remplies avec un détritit sablo-gravieux. Les bas-fonds du type E–G sont des formations plus jeunes à récentes dans la domaine des zones d'accumulation et de sédimentation (régions inondées) des fleuves et des ruisseaux.

1 Introduction

Geomorphological depressions in many parts of Africa are commonly known by names such as *Dambo*, *Mbuga* or *Vlei* (see THOMAS a. GOUDIE 1985). Inside francophone Westafrica comparable surface forms are frequently described by the term *Bas-fond*. Regional expressions for congenial relief-complexes are for example *Fadamas* in Nigeria (TURNER 1975, 1985), *Bolis* in Sierra Leone (STROBBS 1963, MÄCKEL 1979) or *Mare* in Senegal. However, the most usual morphographic designation for lowland-zones is indubitably the expression *bas-fond* descending from French colloquial speech. In a descriptive sense diverse of low-lying surface forms within a planation relief are comprised by the term. *Bas-fonds* could be comprehended as lowlands, depressions, dents, pans, low-terraces, swamps, central- and marginal river sections etc. Caused by monsoonal rainfall events and slow internal drainage the depressions are seasonally flooded and inundated. Mostly their groundwater-level is high up to the end of the dry season. *Bas-fonds* are areas with a great positive water balance. Well developed bigger trees are lacking; grass and her-

^{*)} The field studies took place in the course of two research works relating to regional planning and integrated rural development in co-operation with the GTZ/PNUD-project "Planification Régionale" in Sokodé (Togo) in between 1983–1985.

baceous vegetation dominates the central depression zones.

State of the research and definitions

There are no unified definitions of bas-fonds within scientific literature. KILIAN a. TESSIER (1973: 156) mean by that: "plains inside small and weakly marked valleys that are flooded during the rainy season or where swamps are to be found". Bas-fonds can be divided into a central zone, a slightly inclined slope and a transitional zone in between. As to the drainage system in planation areas bas-fonds hold an important function. RAUNET (1982) classifies bas-fonds "as flat to concave valley sections and small valleys, as well as lowered drain channels which have no clear distinctive stream net". The enduring effect of drainage owing to the depressions is accentuated by the term *tropical valley bottoms* or *inland valley swamps* (RAUNET 1985: 26). BRABANT a. GAVAUD (1985) give a bas-fond description that is more general. According to these authors *bas-fonds* are *diversified, extended, low-lying landscape sections interceding as flat [seasonally inundated] areas between concavely shaped slopes; downstream the depressions are channelless or reveal only a few, little developed features of linear erosion processes*. The presented paper on bas-fonds in Togo is extensively based on the definition of BRABANT a. GAVAUD (1985).

The depressions are suited for plant growing with and without irrigation technics, e. g. cultures of rice and vegetables as well as for water reservoirs, for example wells, drain holes and watering places for man and domestic animals. Particularly during the dry season, the up to now little used bas-fonds represent an extensive agricultural potential. Therefore it is not surprising that scientific research on tropical bas-fonds is mostly effected by agricultural sciences (KILIAN 1972, ARRIVETS 1973, GILLET 1973, GILLIAN 1983). Only recently geosciences have dealt with the subject of bas-fonds. Increasing population pressure in many regions of tropical Africa and the therefore interconnected urgency of an advancing agricultural productivity necessitates besides convenient use of fertilizer and machines, improved selection of species and also the search for additional areas for land use. Fundamental studies covering all areas about geomorphological landscape history, processes of erosion as well as hydrological parameters are basic assumptions for regional planning and integrated rural development that exclusively can provide conditions for a long-term formation of the tropical agrarian landscape.

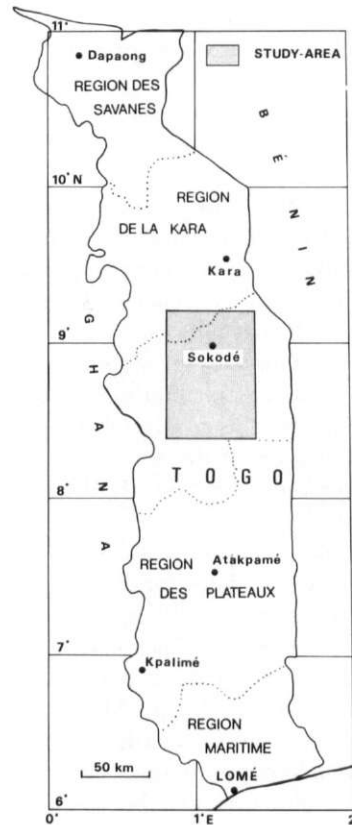


Fig. 1: Location map
Lagekarte

2 Main features of the study area

Location and population

The study area is situated in the middle of the Westafrican state of Togo (56 800 km²) between 7°54'–9°18'N and 0°20'–1°37'E. This area corresponds with the administrative district "Région Centrale" (13 000 km²) that is limited by the "Région de la Kara" in the north and by the "Région des Plateaux" in the south (Fig. 1). The degree of urbanization is generally low. More than 70% of the population lives within a rural environment. The density of population comes to 25 inhab./km² on average; however, there are local densities of population that are much higher (about 50–100 inhab./km²). Inside this region the available land area for agriculture is already cultivated up to 100%. Solely the central zones of numerous bas-fond depressions do not show an intensive land use. The traditional form of agrarian land use is a three to five year crop rotation. The increasing scarcity of arable acreage

leads regionally to long time cultivation cycles with more and more shorter fallow periods.

Geology, geomorphology and soils

Geologically the central region is built up of Precambrian rocks (para- and ortho-gneiss, quartzite, mica-slate and isolated inselbergs of ultrabasic rocks). In the course of the panafrikan orogeny the rock formations passed through an intensive period of metamorphism caused by an east-west orientated collision of two continental margins with consecutive rock over-lapping. This geological division into zones shows a bipartition of the study area. East of the Sokodé-Sotouboua line (Fig. 2) the granite-gneiss basement of the *Dahomeyide's* forms an extended, scarcely undulated planation surface. In the western part weathering-resistant quartzites and mica-slates of the *Atacora* formation build up the Togo-Atacora range (up to 800 m a. s. l.). The ranges of quartzite hills are divided by numerous faults into isolated, inselberg-like massifs (e. g. Mont Sialo east of Sokodé; Fig. 2) and into basins that are spread in front of the main chain of mountains. The main soil types within the study area can be classified by their decreasing frequency into three groups: 1. *Sols ferrugineux tropicaux* (i. e. luvisols, ferralsols and tropical brown soils), 2. *Sols ferrallitiques* (i. e. ferralsols, oxisols, latosols) with widespread lateritic crusts (plinthit) esp. on extended areas of the *Dahomeyide's* planation surface. 3. Soils of the low-lands and depressions, in particular gleysols and stagnosols (*Sols hydromorphes*) which are commonly found inside bas-fonds.

Climate, vegetation and hydrology

The study area belongs to the Westafrican *Soudan-Guinea-Zone*, i. e. transitional climate between the more humid Guinea coastal area and the semi-humid Soudanese hinterland. In the course of the year there is 1100–1500 mm of rainfall in the central region, which is distributed during a rainy season lasting from March/April up to the end of October. Regionally the highest amounts of rainfall are measured in the western parts of the Togo-Atacora range. The territory next to Sokodé and the adjoining planation surface in the South and in the East receive up to an average of 1200–1300 mm of rainfall; within this region the majority of bas-fonds is to be found (Fig. 2). The Guinea moist savanna with sporadic grounds of dense dry forest is the dominating vegetation;

moreover there are some secondary mountain forest formations in elevated regions (> 500 m a. s. l.). The main watershed of the region between the Volta basin in Ghana and the Atlantic ocean runs meridionally in the mountains west of Sokodé. The preponderant part of the study area is drained by the Mono river which flows off southwards to the Atlantic (Fig. 2).

3 Identification of Bas-fonds

Panchromatic black and white air photos are best suited to locate and to map bas-fonds within planation areas. For the investigations in Togo aerial photographs from 1976–1978 with a scale of 1/30 000 were available (Couverture aérienne, République Togolaise à 1/30 000, 76-78 TOG 31/300, IGN-Paris). The stereoscopic analysis of 753 pairs of air photos rendered possible a research covering the whole area of the central region. A section of the mapped area is shown on Fig. 2.

The search for bas-fonds took into consideration generally all kinds of depressions that had clearly come into sight on the air photos because of their geomorphological, hydro-pedological and vegetational features.

Inside the monotonous Togolese planation relief there are striking trough-shaped, evenly lowered, closed and open depressions whose deepest sections are normally flat. Moreover it is remarkable that some of the depressions obviously don't hold a connection to the present drainage and channel net. The ground plan of bas-fonds is a multiform one (see Photo 1a. 2, Table 1). Closed depressions have a round, oval or slightly curved to elliptical form. Open bas-fonds with a superficial connection to the network of rivers are drop-shaped, oval, round, vast or small, elongated to linear and for some part their edges are divided into creek and spur-like forms as well as chained together, net-shaped extended *bas-fonds-systems*. They form *amphitheatre-* and *horseshoe-shaped* recesses at the upper course and at the origin of valleys (MAINGUET 1978: 214). In relation to their surroundings, the depressions in central Togo are relatively low, between five and fifteen meters. The linear and cross expansion varies between 100 to 300 meters in the case of small forms; larger bas-fonds can reach dimensions of 1000 up to 3000 meters. By modified conditions of soil, ground water and vegetation on the air photo, the bas-fond is sharply separated from its environment. Smooth or less structured brinks enclose the deepenings. On black and white air

photos the depressions' centres are reproduced by dark grey to pale grey colours (Photo 1 a, 2). The edges of the bas-fonds dependant on the surface's morphology can easily be recognized by remarkable variations in colours between the mostly incrustated, flat watershed slopes and the central depression zones (compare ACRES et al. 1985). The dark grey lined depressions frequently show a granulate-like, grey white to light grey belt with some ten meters of extension that surrounds the bas-fonds in the transitional zone to the planation surface. Moreover, one can observe within the grey coloured depression surface, a marbled ground pattern formed by single and fine drain channels, mostly developed on bas-fonds slopes. On the one hand some of these drain channels are discontinuously formed and do not reach a principal water course. On the other hand incised channels go through and lead down to the deepest parts of the depression. Gullies eroding from a channel's upper course into the central and flat bas-fond area can also frequently be found (Photo 5). Some trees are to be recognized inside the depressions; mostly they grow on elevated and therefore drier positions, often on old and degraded termite mounds. In the densely populated areas of Central-Togo between Sokodé and Sotouboua, numerous bas-fonds are situated (Fig. 2). The inner zones are excluded from agrarian utilization. Therefore characteristic land use patterns that keep the depressions mostly unused are also an instrument for the easy identification of bas-fonds on aerial photographs.

Photo 1 (located on Fig. 2) shows on air photo of an intensively agrarian utilized section near to the village of Yelivoh, east of Sokodé. The fields are situated on the transitional domains and shallow slopes between the tops of the interflows and the depressions. Here, less structured, oval to oblong depressions are to be found at the upper course of seasonally water-bearing channels. By bay-like forms the bas-fonds spread into higher parts of the interflows. Downstream, the depressions rejuvenate to low-land and to meadow-like margins that follow the drain channels over a distance of several hundred meters. The proportion of longitudinal to transversal extension of mostly round to oval bas-fonds is between 2:1 and 4:1. The second example (Photo 2) shows with a comparable intensity of land use larger and more extended bas-fonds forms. An almost circular and large depression in the upper part of the opening resembles primarily a "pan" independant of a watercourse that has accumulated, as a sediment trap, eroded surface material. Also this bas-fond is straitened downstream and turns to a system of low-

terraces that accompanies the drain channel over several kilometers. In this case there are a lot of similarities between a river's stream net and the nature of wide-spread *bas-fonds-systems*. On the southern margin of the central region the water flood net is clearly marked by bas-fonds (Fig. 2).

4 Distribution of Bas-fonds

More than 3000 geomorphological depressions were mapped inside Togolese central region. The black spots in Fig. 2 represent low-lying and flat surface areas including marginal slope zones of shallow watersheds within the planation relief. The bas-fonds and their corresponding amount of area are not equally distributed over the study area. There are marked regional distribution patterns of bas-fonds that will be investigated under aspects of geology, geomorphology and soils as well as by the allocation of population and land use.

Bas-fonds and geology

The largest accumulation of bas-fonds appears on the western periphery of the *Dahomeyide's* granite-gneiss basement between Sokodé and Sotouboua. This zone corresponds with the region of high Pan-African metamorphism and the geological passage to the *Atacora* formation. It must be assumed that there is a close relationship between rock composition and geological faults for bas-fonds formation. Apart from this the north-south leading ribbon of bas-fonds (10–20 km wide) is situated in an area of predominantly ferrallitic soils with extended iron crusts.

Bas-fonds and geomorphology

There are further interrelationships between the mean inclination of slopes and the density of drain channels with regard to bas-fonds' distribution. Within the region of the iron incrustated planation surface with a characteristic relief of *interfluvies* (extremely flat watersheds) more than 80% of the surface belongs to the slope inclination class of 1°–3°. The landscape's appearance is dominated by widespread, shallow convexly-shaped rises that build up a wavy and undulated relief where bas-fonds are to be found in between. Steepest slopes on the planation surface reach inclinations of about 5°–6°, representing shorter sections (< 50 m) near to weathering resistant

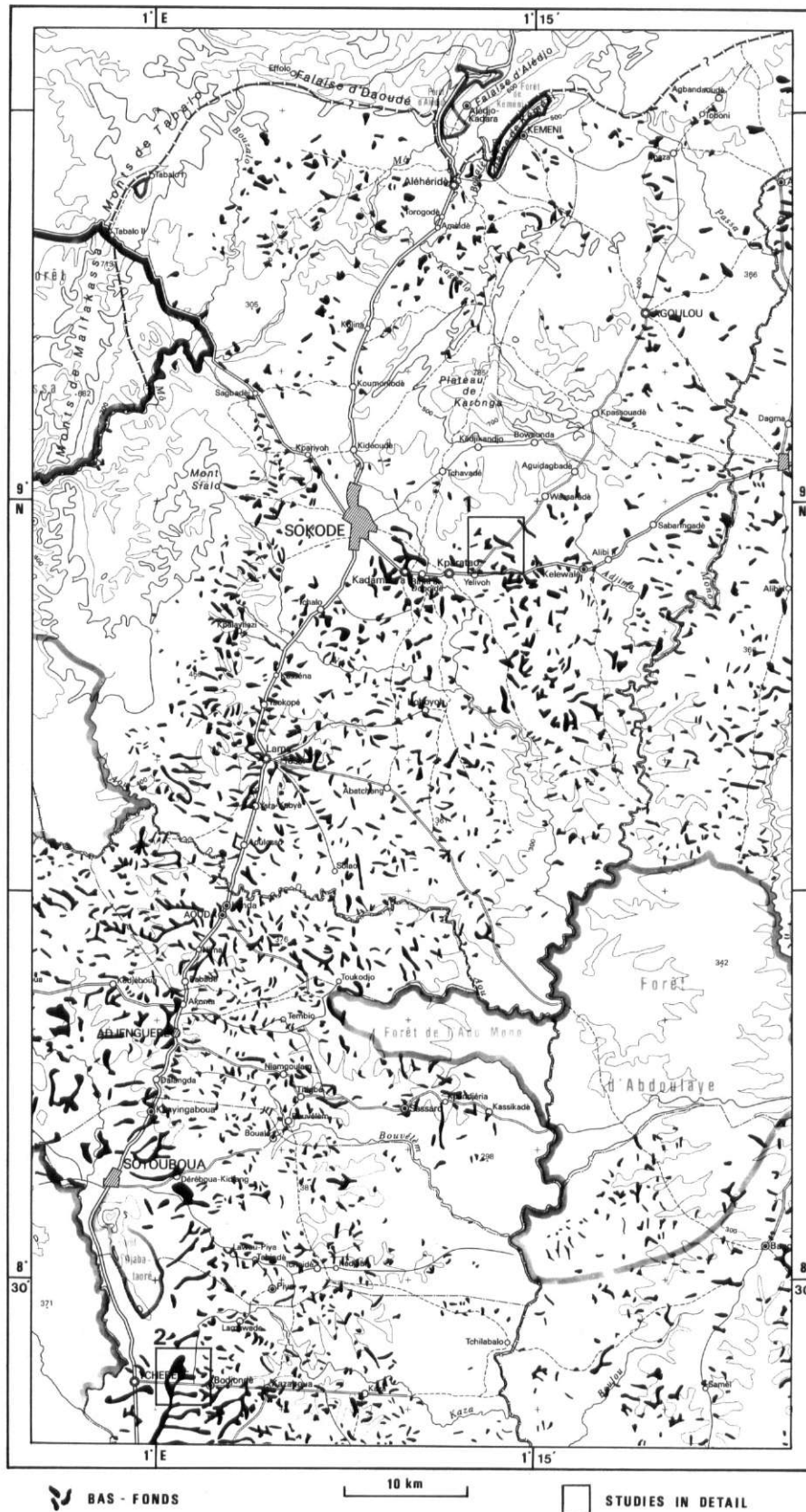


Fig. 2: Distribution of bas-fonds (the depressions within the grey framed national parks are not considered)
 Bas-fonds Verbreitung (die Depressionen innerhalb der grau umrahmten Nationalparks sind nicht berücksichtigt)

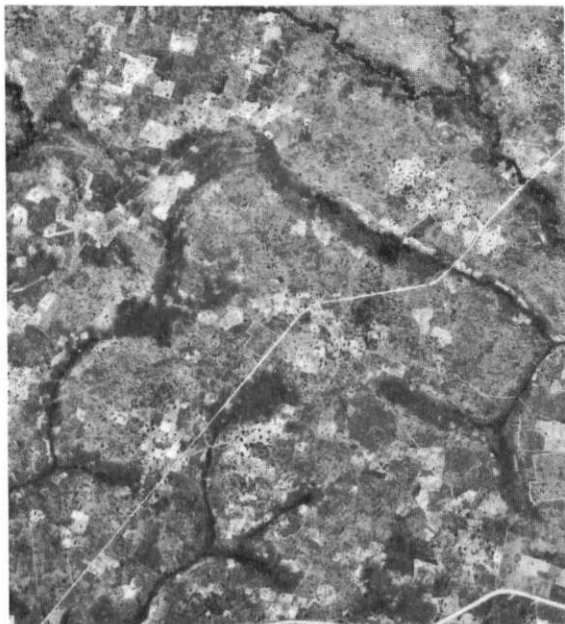


Photo 1: Aerial photograph No. 1587 (77 TOG 31/300, IGN 1976/78). Cut-out (5 × 5 km large) of the planation surface, run through by bas-fonds near Yelivoh (see Fig. 2)

Luftbild Nr. 1587 (77 TOG 31/300, IGN 1976/78). Mit Bas-fonds durchsetzter Rumpfflächenausschnitt (5 × 5 km) bei Yelivoh (siehe Fig. 2)



Photo 2: Aerial photograph No. 2883 (77 TOG 31/300, IGN 1976/78). Continuous 'bas-fonds-systems' near Tchebébé (cut-out 5 × 5 km, see Fig. 2), marking the drainage net of the planation surface

Luftbild Nr. 2883 (77 TOG 31/300, IGN 1976-78). Zusammenhängende 'Bas-fonds-Systeme' bei Tchebébé, die das Gewässernetz der Rumpffläche nachzeichnen (Ausschnitt 5 × 5 km, siehe Fig. 2)

lateritic scarps. The western limit of bas-fonds' occurrence (Fig. 2) is to be found there where average inclination rates are higher than 6°. Above this threshold value of about 6° erosion is dominating sedimentation. Here bas-fonds appear only near to river plains inside hilly areas. If the density of drainage patterns on a peneplain is high and somewhat dendriform, small bas-fonds at the upper course of streams and pan-like depressions on watersheds are to be found. If the density of drainage patterns is middle to low and surface inclinations are lower than 1°, widespread and meadow-like bas-fonds are developed and partly distributed over the whole river net (Photo 2).

Bas-fonds and population (land use)

Moreover, the area with highest bas-fonds' occurrence coincides with the mostly populated and land used zone. The bas-fonds' centres are not intensively used by farmers (Photo 1 a, 2). Whether there is an anthropogenic influence on the appearance of bas-fonds by land use and soil erosion can not be easily

answered at present. Strengthened agricultural activities and bush fires, initialized by man could have definitely led to an increased rate of erosion and at the same time to an accumulation of sediment in the pre-given geomorphological depressions. As sediment traps, bas-fonds are sometimes suited to reconstruct holocene periods of environmental change; for example extracting information about the history of settlements by artefacts that were kept inside bas-fonds' colluvial soils (see FÖLSTER 1969 with examples from Nigeria).

5 Classification of Bas-fonds

Seven types of bas-fonds are to be distinguished. The classification pays attention to a bas-fonds' ground plan and its drain position (situated at the upper-, middle- or lower course). Two main groups of bas-fonds can be discerned. One group of closed and open depressions that are developed at upper course drain positions or next to watersheds. The basic form of these bas-fonds (type A-D) is generally

Posit.	TYPE	DESCRIPTION	DISTRIBUTION	%	SKETCH
					300 m
Upper course	A	round to oval, closed depression without fluvial drain or developed stream channel	very rare, type A can be found in the upper parts of iron incusted flat watersheds (interfluves) near to Kazaboua (see fig. 2)	1 - 2	
	B	circular, oval to oblong, open depression without central gallery forest and absence of well developed stream- or drain channel	frequently occurring bas-fond form in the studied area, esp. all along the national road 1 between Sokodé and Sotouboua	50	
	C	oval to oblong with characteristic sub-divisions of ramifications and bas-fonds "branches"; weakly developed stream channels and absence of gallery forest	numerously occurring depression type formed by connection of bas-fonds type B; examples in the area of Aoulossou and east of Lama Tessi	15 - 20	
	D	oblong to linear, stronger incised within the planation surface; central depression zone without developed stream channel and gallery forest; sometimes with wave-like ground plan	field examples esp. east of the Mono river near to the villages of Kambolé and Goubi, as well as in the neighbourhood of Sokodé (Birini)	10	
Middle course	E	single streamside and seasonally flooded depression bounded by river channel and formations of gallery forests	rare, in the environment of larger meandering stream channels (e.g. Mono river) on the granite-gneiss planation surface	5	
	F	bas-fond depression (triangle-shaped flood-zone) situated at the confluence of two or more incised drain channels; presence of dense gallery forest formations	frequent at small delta areas with flat slopes and high drainage channel density	2	
	G	extended bas-fond depression (floodplain, low-terrace) along the river channel with well developed gallery forests	esp. in the western parts of the central region (not to be discerned on fig. 2) with extremely flat watersheds and low drainage channel density	10	



Bas-fond (central zone)



Slope



Gallery forest



River and stream channel

Table 1: Classification of bas-fonds in the 'Central Region' of Togo (with percentage of each geomorphological depression type)

Bas-fonds Typisierung in der 'Zentralregion' Togos (mit prozentualen Anteilen der jeweiligen geomorphologischen Depressionstypen)

round to oval (Table 1). The other group represents bas-fonds that could be described in a wider sense as low-terraces and periodically inundated swamps along stream channels and river banks (type E-G). Bas-fond types of Central-Togo are shown in Table 1 with a detailed description of their appearance on air photos and locations of characteristic forms inside the study area.

Hypothesis on the dynamic development of Bas-fonds

Bas-fonds form dynamic continua within an unlimited landscape. Therefore it is understandable that these morphological forms have not always been constant. Similar to a landscape, bas-fonds form a dynamic system of different geomorphological processes.

The use of the interpretation key from Table 1 shows at an early stage that it is not possible to classify all depressions exactly to one or another bas-fond type (A-G). This implies that besides clearly definable, single bas-fonds types, a lot of transitional states in between "individually" outformed depression are to be recorded. These transitional forms are dependant on time- and climate influenced morphodynamic processes that have effected over a long lasting period a progressive modification of the lowlands. Speculations about the development of single depressions become feasible solely by indirect morphographic investigations supported by remote sensing technics. Therefore a bas-fond type A is to be considered in that way that the geomorphic advancement of this form tends to develop a superficial drain channel; then type A turns into type B; or some separated, but adjacent "pans" of type A will unite and form a new and a larger depression – bas-fond type C has come into existence (see Table 1).

As an indication to the correctness of the proposed hypothesis that geomorphological processes tend to unite small and single bas-fonds to bigger and extended bas-fonds systems, strongly curved marginal sections on the bas-fonds' ground plans must be taken into consideration. These wavy border structures of many depressions (Photo 2) can be interpreted as relics of formerly existing closed slope framings around the depressions as shown in the case of bas-fond type A. The development of bas-fonds favours the rearward extension of stream channels by letting down small depressions within tropical planation surfaces. Apparently fluvial drain systems make use of the depressions as developing and guiding lines for retrogressive erosion processes that lead to a progress-

ing disintegration of the planation relief (Photo 4 a. 5). If the process is continuing, the *older* and higher surface will be totally destroyed and lowered – a new surface is formed out in the long run. Rate and efficiency of expansion in area of bas-fonds mostly depends on climate (amount of rainfall and distribution of rainfall), corresponding drain basins, vegetation cover and weathering resistance of surrounding interflows (i. e. covered by iron/lateritic crusts or not?). The proposed model of further morphographic development of bas-fonds with continuous increase in total low-land area clearly explains multiform ground plans of schematized depressions of type A, B, C and D.

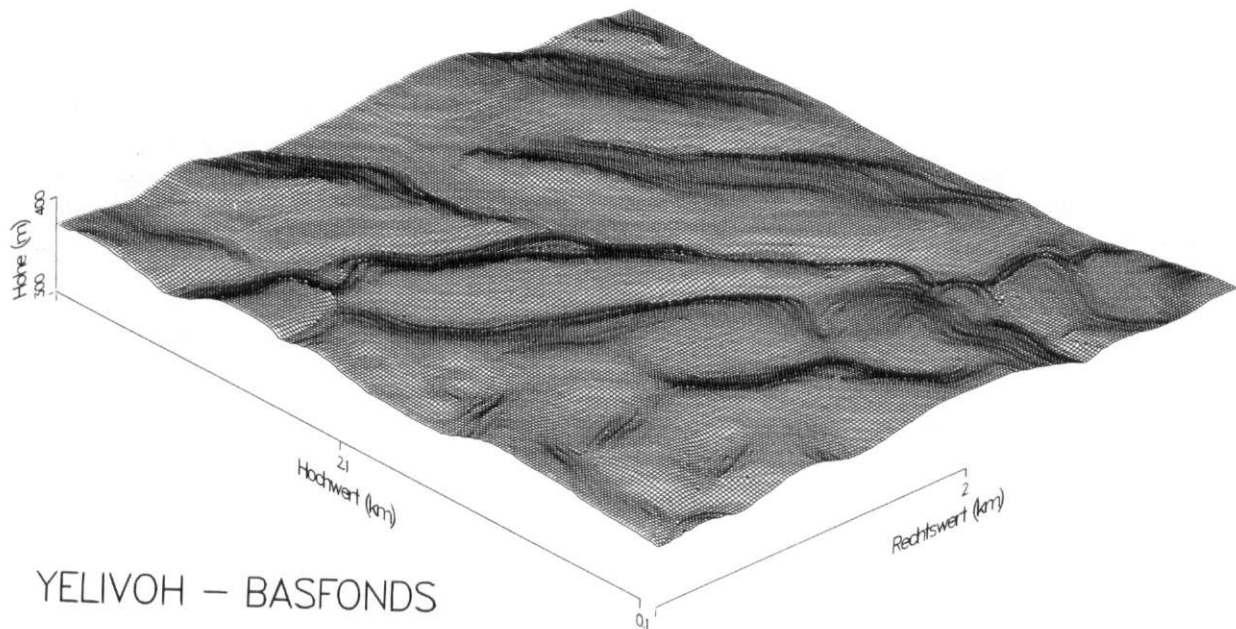
6 Field studies (Bas-fonds near Yelivoh)

Morphometric evaluation

Flat and extended bas-fonds are not to be shown by contours in the 1/50 000 topographical maps (publ. by IGN-Paris 1958–1969). Morphometric evaluation of aerial photographs allows further perceptions on the morphology and the appearance of bas-fonds. By double projection of a stereo pair of air photos (No. 1586/1587, TOG 31/300, IGN-Paris 1976–78) with ZEISS "DP 1" additional contours with lower intervals could be manually drawn in. With the help of a digital landscape model a block diagram of a part of the Togolese planation surface interspersed with bas-fonds is designed (Fig. 3). The opening on the block diagram presents the same section of the planation area that has already been discussed with regard to Photo 1. The computer drawn landscape (Fig. 3) shows by many details the organization of the planation relief in bas-fonds and in flat watersheds. Statistically determined values of average slope angles where the depressions are best developed run from 1,7° to 2,5°, within the Yelivoh study area (Fig. 2 and Photo 1).

Transversal and longitudinal cross-sections

Transversal cross-sections of bas-fonds are symmetrically composed. Beginning with a flat plateau-like, slightly curved up interflow, an elongated, sometimes concavely sunk in slope section (1°–4°) intercedes to a small plain situated within the depression's centre. Longitudinal cross-sections differ by lack of profile symmetry originating in a superficial drain channel.



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Fig. 3: Computer designed block diagram of bas-fonds near Yelivoh (see Photo 1)

Computerblockbild der Bas-fonds bei Yelivoh (siehe Photo 1)

In the field a bas-fond begins imperceptibly within partly shrubby areas of the Guinea moist savanna consisting of trees like *Parkia biglobosa*, *Vitellaria paradoxa* and *Prosopis africana* on top areas of flat watersheds. Pisolites and loose sandy surface material, transported and accumulated by sheet-wash, cover the interflow's surface unequally that is exclusively overgrown by woodland. The ground itself is mostly free of other vegetation. Getting closer to the depression, slope inclinations increase insignificantly up to 1° or 2° . Lateritic outcrops of 30–50 cm in height stand out of the slope because of their resistance to weathering processes. Lateritic crusts disappear on certain parts of the slope; in this place 20–30 cm thick layers of hillwash, also composed by pisolites and gravel deposits, overlap the iron crusts. Nearer to the depression's centre, lateritic crusts and pisolites remain behind, the savanna woodland thins out (Photo 3), shrubs and grassland start to dominate the scenery. Most of the grassland is burnt by bush-fires at the beginning of the dry season. The middle slope of the bas-fond is almost rectilinear with inclinations of 2° – 3° . It is stronger slanted than the laterite incrustated upper slope (Fig. 4). A great many of lightly beige coloured termite mounds (up to 50 cm high) characterize this middle section. Generally phenomena of bioturbation are often noticed. Besides termites and ants especially worms are responsible for

mixing up and displacing upper soil horizons in connection with sheet-wash processes. The vegetationless ground of the middle slope is covered by a thin



Photo 3: View of a bas-fond type B (see Table 1), 10 km southwest of Sokodé. In the rear a dense savanna forest, extending on convexly shaped, flat watershed slopes can be observed. Borassus palms in the grass covered centre mark concentrated surface run-off (15. 12. 1983)

Ansicht eines Bas-fonds vom Typ B (siehe Tabelle 1), 10 km südwestlich von Sokodé. Im Hintergrund erkennt man auf den ausgedehnten, flachkonvexen Wasserscheiden einen dichten Savannenwald. Borassuspalmen im grasbestandenen Zentrum der Niederung kennzeichnen den konzentrierten Oberflächenabfluß (15. 12. 1983)



Photo 4: Smaller bas-fond type B or C in the eastern part of the central region. The high groundwater level is indicated by a fresh grassland cover of *Imperata cylindrica*. The edge of the depression is marked by a lateritic scarp that is situated in the background several meters higher on the planation surface (12. 2. 1984)

Kleinerer Bas-fond des Typs B oder C im östlichen Teil der Zentralregion. Der hohe Grundwasserspiegel wird von einer frischen Grasbedeckung aus *Imperata cylindrica* angezeigt. Der Rand der Depression wird durch eine mehrere Meter hohe Lateritstufe im Hintergrund auf der Rumpffläche deutlich (12. 2. 1984)

layer of sand in which small iron- and aluminium concretions (<1 cm) are to be found. Next to the flat centre there is a waste middle to coarse-grained sandy strip that encloses the grass-grown depression. This concavely shaped strip is a kind of "shore-line" of short time "bas-fond-lakes" in connection with violent rainfall during the rainy season. Large amounts of transportable and eroded sediments are carried downwards by morphologically effective sheet-wash processes inside the bas-fond that is flooded because of insufficient drainage. The process can clearly be reconstructed by former, now totally eroded and destroyed *buttes* of yam and manioc; concentric spots of one meter in diameter have been left as a typical ground pattern. The high morphodynamic activity and erosivity along marginal concave profile sections (*washzone*, after MÄCKEL 1975) explains why local farmers tend to avoid such locations. The grass cover in the bas-fond's lowest section consists of worthless hard grass formations like *Imperata cylindrica* (Photo 4), whose development is favoured by human impact, for example by regular bush-fires.

Soil catena

Following the preceding sub-divisions of bas-fonds' cross-sections, three soil profiles are investi-

gated (Fig. 4). Opening (3) has an extremely low thickness of soil (<50 cm) and consists nearly to 50% of lightly deposited pisolites and Fe/Al-concretions. Further 45% of texture is sand; clay content is below 5%. The colour of the surface soil is brown grey to grey brown (MUNSELL COLOUR: 10 YR 3/2), lateritic sub-soil and underlying lateritic turn into a reddish brown shade (5 YR 4/4-4/6). The second soil profile (2) is situated on the elongated middle slope (Fig. 4). In the top-soil (2-5 cm) a loose and sandy textured layer with occasional pisolites and coarse fragments is to be recognized. Soil colour is yellow grey or brightly sand-coloured (2,5 Y 4/2). Below that, up to a depth of 30 cm, the texture is compact and homogeneously sandy. Generally soils are little rooted; soil colour has now changed into grey brown (10 YR 5/3). In the following layer, clay content increases equally whereas the portion of sand and skeleton soil decreases. In 150 cm depth, the content of clay has already reached more than 30% as opposed to only 5% in the top-soil. Below 150 cm, for the first time rusty bands and spots as well as scattered pisolites appear. These concretions have been transported by former sheet-wash events into the depression, or they could also have been formed there, effected by periodically altering soil moisture conditions from wet to dry and vice versa. Soil colours have turned into grey to grey brown tones (7,5 YR 6/3).

Opening (1), situated in the bas-fond's centre (Fig. 4), presents different conditions. The clay- and silt-content of the top-soil is high (>60%). This is to be explained by accumulated fine soil textures that had been eroded and transported by processes of sheet-wash inside the "sediment trap" bas-fond. Also deposition of suspensions from episodically formed "bas-fond-lakes" must be taken into consideration. During the dry season several big contraction strains up to 20 cm in depth can be noticed all over the inner bas-fond zone. Comparably high contents of carbon (4%) dependant on self-mulch effects are registered for top-soil sections. Turning to the sub-soil, clay content is primarily decreasing when some characteristic layers of sandy texture (several centimeters thick) appear. Such isolated sandy layers of mostly coarse grain indicate that the depressions are real accumulative forms that were filled up by sediment within several holocene erosion and sedimentation phases. The grey coloured texture of this colluvisol is stronger consolidated than the other openings and shows at the same time processes of bioturbation mostly effected by termites. Besides the above mentioned single layers, the composition of soil profile (1) is relatively homogeneous. Therefore it is difficult to

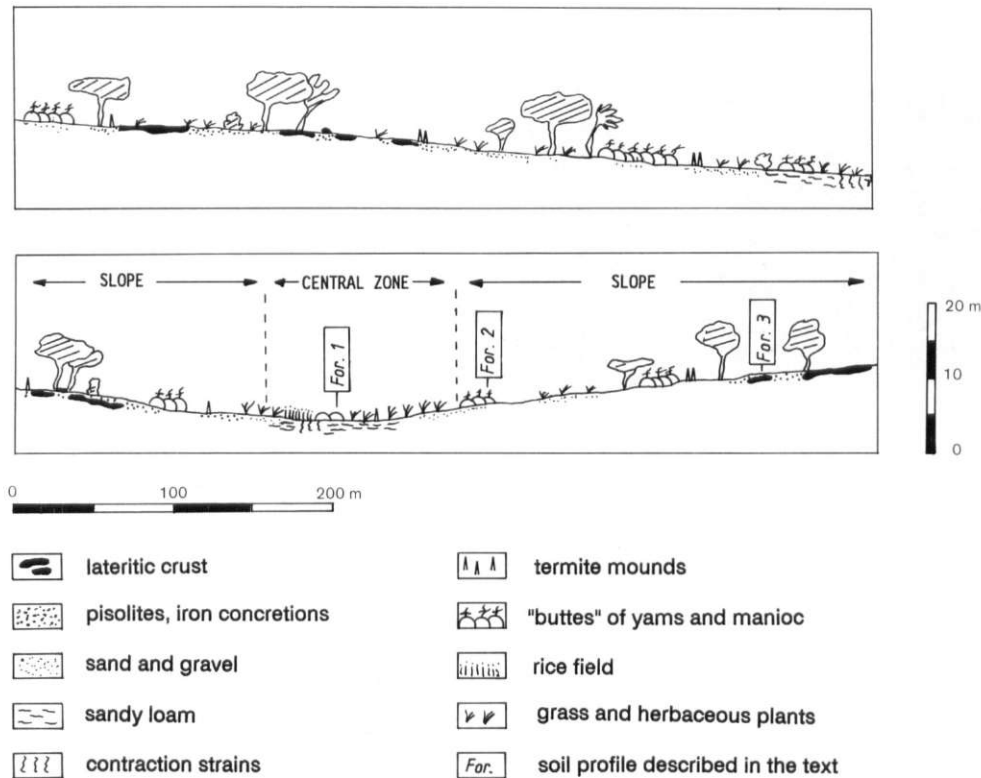


Fig. 4: Transversal and longitudinal cross-profile of a typical bas-fond
 Quer- und Längsprofil eines typischen Bas-fonds

interpret the once accumulated but today mostly bioturbately mixed up sediment as indicators for holocene environmental change. Below a depth of 150 cm features of hydromorphic soil conditions are visible and even at the end of the dry season the bas-fond's ground water level can be reached in more than two meters in depth.

The average thickness of sediment that has been transformed pedogically inside the bas-fonds reaches two or four meters in depth. The transition to the intensely weathered and saprolitized basement takes place continuously without any marked bounding surface. The reason for insufficient drainage of the depressions is in the first place due to the lowering of the geomorphological form itself and secondly to the underlying basement that forms an impermeable bed. The distribution of clay and lessivation processes, together with bioturbation play an important role for local variations in limited infiltration rates of bas-fonds' soils.

From the morpho-pedological viewpoint soils within bas-fonds are allochthonous infillings of sediments that were accumulated over a longer period of time into pre-given, low-lying relief com-

plexes. Later on these colluviosols and detritic layers have been transformed by pedogenesis and have continuously been mixed up and sorted out by bioturbation. Investigations of the question if there could have been a paleoclimatic induced aeolian infilling of sand into the depressions, showed no signs of a former wind erosion process under arid conditions. Further there is a close mineralogically affinity between bas-fonds' sediment and other solid rocks within the study area.

7 Geomorphological evolution of Bas-fonds (Conclusions)

Like the planation of the Precambrian *Dahomeyide's* basement, the formation of bas-fonds has been a long lasting process with an earth history duration. Therefore the geomorphological evolution of these striking relief forms can not be satisfactorily measured or undoubtedly be reconstructed. However, the application of the *principle of actualism* allows, with regard to a series of field observations on present-day and on former morphodynamic processes, to deduct a schematized bas-fond model (Fig. 5).

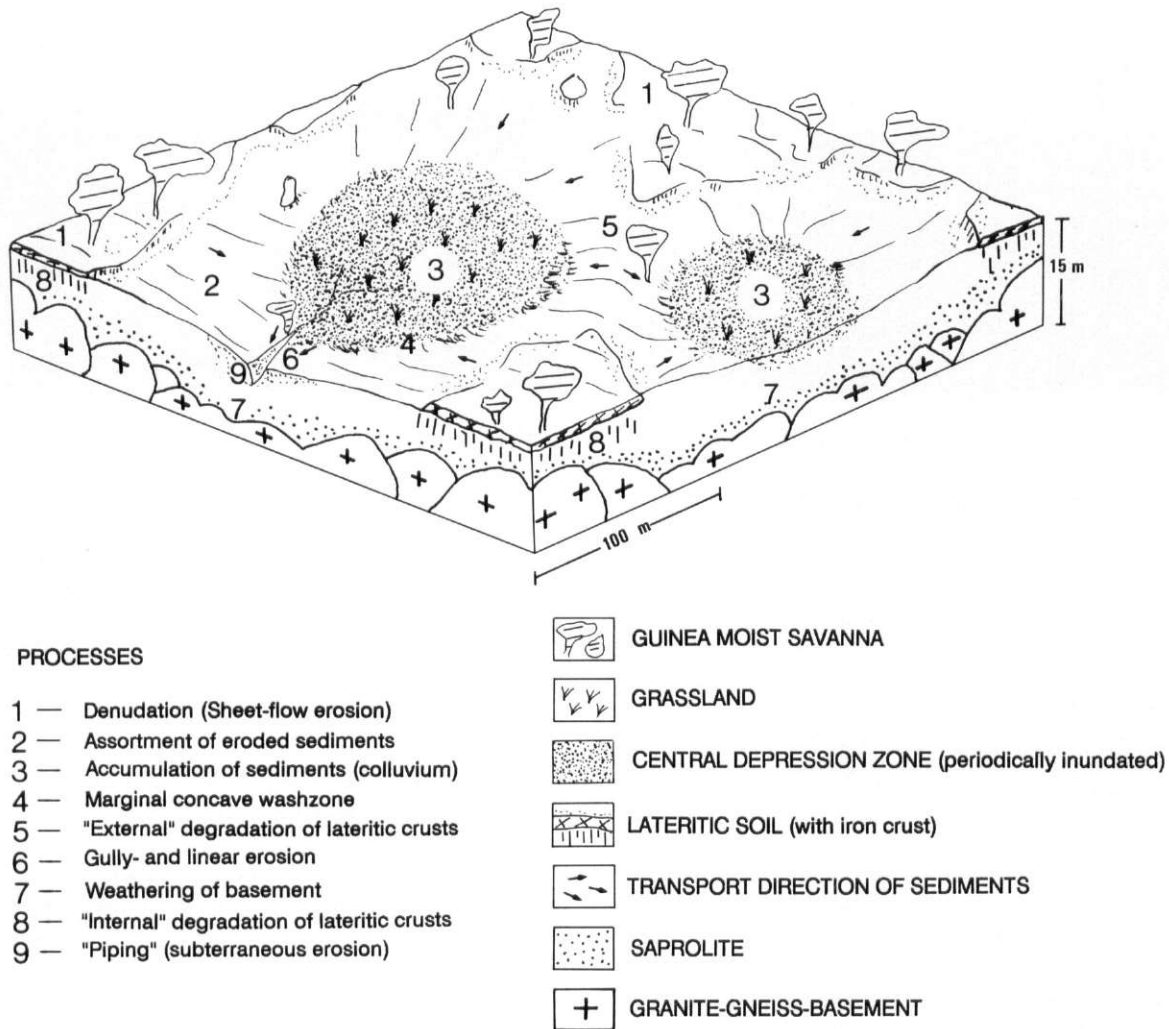


Fig. 5: Morphodynamic bas-fond model of Central-Togo
Morphodynamisches Bas-fond Modell von Zentral-Togo

Field investigations almost exclusively showed that the bas-fonds are associated and closely related to outcrops of lateritic crusts. Within such environments the depressions have characteristic round to oval, closed or open ground plans (Table 1). Morphodynamic processes that lead to a transformation of laterite incrustated and extended peneplains into stronger undulated geomorphological conditions are important for bas-fonds' morphogenesis. Weathering processes that initialize the degradation of iron crusts by mechanical and chemical means, cause the differentiation of a peneplain into a wavy surface, composed of numerous *interfluvies* and *bas-fonds*. These "external" and "internal" processes of lateritic crusts' disintegration (Fig. 5) take place recently all over Westafrica (LEPRUN 1979). External, super-

ficially acting morphodynamic processes are denudation and sheet-wash, assortment and accumulation of sediment, retrogressive erosion and beheading (processes no. 1-6, Fig. 5). Internal, subterraneously acting processes are dependant on faults and on rock composition with lateral groundwater flow and selective weathering, solution, subsrosion and pseudo-karstic modifications of the entire lateritic crusts as well as "Piping" (processes no. 7-9, Fig. 5). Comparable observations that support the idea of pseudo-karstic phenomena in laterite terrains were published by GOUDIE (1973: 48) for western India and by McFARLANE (1976: 60) for central and southern Africa. From Sierra Leone extended cave-systems with drain channels underneath of massive lateritic crusts were described by BOWDEN (1980: 81). Tem-



Photo 5: Advancing linear erosion on downstream sections of bas-fond Birini (type D), 8 km east of Sokodé (see Fig. 2). Oil palms and riverine forests attend the gully-system that has already reached a depth of two meters. In the foreground burnt grassland and signs of sheet-wash processes with high concentration of quartz grains and lateritic gravel are to be found (27. 2. 1985)

Fortschreitende Linearerosion an den unteren Abschnitten des Bas-fond Birini (Typ D), 8 km östlich von Sokodé (siehe Fig. 2). Ölpalmen und Galeriewälder begleiten das Gullysystem, das bereits eine Tiefe von zwei Metern erreicht hat. Im Vordergrund abgebranntes Grasland mit Hinweisen auf spüldenudative Prozesse durch oberflächlichen Quarz- und Lateritschutt (27. 2. 1985)

porarily the lateritic crusts break down because of the subterraneous caves. Collapsed "dolines" and deepenings surrounded by lateritic scarps are formed out. Of course, it seems that the Togolese bas-fond depressions had never been real "sink-holes" or collapsed surface forms with steep slopes, as described above. The results of the field studies and the aerial photo interpretation point at a geomorphological evolution of bas-fonds as originally larger and smaller zones of subsidence and subsrosion within an extended laterite terrain. Initially bas-fonds' genesis is influenced by combined effects of subterraneous erosion processes, causing a strong surface disintegration, especially on lateritic crusts. Sheet-flow erosion, which is the dominating morphodynamic process for the related *dambo* formation (MÄCKEL 1975: 15), is not such important for bas-fond development. In Central-Togo, denudational processes superficially modify the already pregiven subterraneously formed out bas-fonds. As a secondary effect of sheet-wash, eroded interflow material is accumulated within the depressions.

Summarized by six thesis the geomorphic development of the central Togolese bas-fonds might have passed as follows:



Photo 6: View of a bas-fond type B at the northern edge of the central region. This depression had been utilized by man for fish-hatchery; the depression's drain channel (in the picture on the right side) is locked up by an artificial dam (1. 12. 1983)

Blick auf einen Bas-fond des Typs B am nördlichen Rand der Zentralregion. Diese Depression wurde zur Fischzucht genutzt; der Abfluß der Niederung (im Bild rechts) ist mit einem künstlichen Damm verschlossen worden (1. 12. 1983)

1. Formation of a planation surface during the Tertiary era connected with the development of extended areas of lateritic crusts.
2. Degradation of the weathering-resistant lateritic crusts under changing, sometimes humid climatic conditions. Subterraneous weathering and erosion leads to a partly disintegration and to local zones of subsidence of the incrustated plateau areas (formation of bas-fond pans).
3. Dedritic gravel and other weathered crust material of the planation surface is accumulated inside the "sediment traps". Sheet-flow superficially modifies and favours the connection of separated bas-fond pans.
4. Bas-fonds drain the planation surface. Because of Quaternary climatic oscillations from semi-humid to semi-arid, colluvial sediment is accumulated inside the depressions and pedologically and bioturbately modified.
5. Further beheading of mostly all closed bas-fond pans by retrogressive erosion processes and a generally extension of the drain channels' net.
6. Strong fluvial dissection and degradation of the bas-fonds' centres (favoured by human impact) by gullying and removal of formerly accumulated fine-sediment into the watercourses (= conditions at present, see Photo 5).

Bas-fonds type E-G (Table 1) at the middle- and the lower-course of streams and drain channels repre-

sent "younger" to recent accumulations of sediment at suited topographic positions. In the course of high flood waters and inundations fine sediment is deposited in these preferable zones (= flood plain deposits, alluvium). Generally, the central Togolese bas-fonds are comparable to many of the also very multiform fadama-lands of Nigeria.

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