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# SOME ASPECTS OF STONE-LINES AND DISSOLUTION FRONTS ASSOCIATED WITH REGOLITH AND DAMBO PROFILES IN PARTS OF MALAWI AND ZIMBABWE

BY

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SUMMARY. – Stone-lines associated with the African Surface in parts of Malawi and Zimbabwe occur locally at the interface between saprolite and superficial materials. The roundness or angularity of the stones, predominantly quartz, relates to the state of weathering of the feeder stringer in the saprolite. Where there are no stringers, the interface is diffuse or delicately convoluted, with saprolite clasts suspended in the materials above it, features typical of an intracutaneous dissolution front. The association of stonelines with this front leads to the conclusion that they are essentially residual. This applies to all three catenary positions, interfluve, dambo-peripheral and dambo. The configuration of the interface is irregular and there is evidence for both small and large scale basining. Large scale basins are occupied by discrete dambos with internal drainage, evidenced by piping at their base. The mineral evolution at the dissolution front in a freely-draining profile showed that removal of kaolinite is associated with saprolite collapse to yield the sandy superficial residuum. Micro-organisms from this and other profiles were shown, by leaching experiments, to effect kaolinite destruction.

RÉSUMÉ. – *Quelques aspects des stone-lines et des fronts de dissolution associés aux régolithes et aux sols de dembo dans diverses parties du Malawi et du Zimbabwe.* – Les stone-lines associées à la Surface Africaine dans certaines régions du Malawi et du Zimbabwe apparaissent localement au contact entre la roche altérée et les produits superficiels. L'émoussé des cailloux, principalement du quartz est en relation avec l'état d'altération des filons dont ils dérivent. Lorsqu'il n'y a pas de filon, le contact est diffus ou légèrement ondulé avec des débris de roche altérée dans les terrains superficiels, phénomène typique d'un front de dissolution "intracutané". L'association de stone-lines avec un tel front permet de conclure à leur origine résiduelle. Cette conclusion s'applique à tous les points de la catena : interfluve, marge et centre du dembo. La configuration du contact est irrégulière, montrant l'existence

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de cuvettes de différentes dimensions. Les cuvettes les plus grandes sont occupées par de petits dembos au drainage interne mis en évidence par la suffusion présente à leur base. L'évolution minéralogique dans le front de dissolution dans un profil bien drainé montre que le départ des kaolinites est associé à l'affaissement du saprolite pour fournir le matériel résiduel sableux. Les micro-organismes récoltés dans différents profils sont capables de détruire la kaolinite comme l'ont montré des expériences de lessivage.

SAMENVATTING. – *Sommige aspekten van de stone-line en de oplossinsfronten verbonden met regoliet en "dambo"-profielen in delen van Malawi en van Zimbabwe.* – De stone-lines geassocieerd aan de "African Surface" in bepaalde streken van Malawi en Zimbabwe, komen plaatselijk voor aan het kontakt tussen de saproliet en de oppervlakte-materialen. De afgeronde of hoekige vorm van de gesteentefragmenten, vooral van het kwarts, staat in verband met de verweringstoestand van de aders waaruit zij voortkomen. Indien er geen ader is, is het scheidingsvlak diffuus of lichtjes gegolfd, met saprolietresten in de oppervlaktematerialen, typisch fenomeen van een "intracutaan" oplossingsfront. Uit de associatie van de stone-lines met een dergelijk front kan men hun residuele oorsprong afleiden. Dit besluit is toepasselijk op de ganse catena : interfluvium, rand en centrum van de dambo. Het uitzicht van het scheidingsvlak is onregelmatig, en toont het bestaan aan van bekkens van verschillende afmetingen. De grootste bekkens worden ingenomen door kleine dambos met interne afwatering, duidelijk aangegeven door piping aan hun basis. De mineralogische evolutie in het oplossingsfront in een goed gedraineerd profiel toont aan dat het verdwijnen van kaoliniet leidt tot de verzakking van de saproliet en het ontstaan van zandig residueel materiaal. De micro-organismen uit verschillende profielen gehaald, zijn ertoe in staat het kaoliniet te vernietigen, wat proefondervindelijk door uitlogingsexperimenten werd aangetoond.

## Introduction

The African erosion surface survives extensively in Malawi (LISTER 1967) and is well represented along the main watershed in Zimbabwe (LISTER 1979). In both cases the terrain is characterised by low relief, punctuated by inselbergs, koppies, dwalas or other forms of fresh rock outcrop often in interfluve positions or near localities where stream incision is most active and associated with encroachment of younger surfaces upon the African Surface. This paper presents observations and data from two areas of African surface, the Lilongwe area of Malawi and the Seki and Wedza districts, south east of Harare in Zimbabwe.

In both areas the regolith profiles have a sandy or clayey surface mantle or colluvium overlying *in situ* saprolite of variable depth. Weathering is essentially non-lateritic in profiles developed from acid basement rocks (granite and gneisses) that is, iron and aluminium are not retained and do not accumulate relatively (SCHELLMANN 1981) in the freely draining interfluve profiles, but there is some formation of laterite by absolute accumulation in slope bottom situations adjacent to the lowest landscape components, the dambos. These are seasonally waterlogged areas with surficial horizons rich in smectitic and kaolinitic clays. This paper is concerned with the nature of the boundary between *in situ* saprolite and the surficial materials in the three catenary positions, interfluves, dambo-peripheral areas and dambos.

## Interfluve profiles

Stone-lines are commonly exposed in road cuttings in interfluve positions. Often they are of limited extent, occurring where quartz bands or stringers in the saprolite feed into the collapsed surficial horizon or colluvium. Above these quartz feeders the stonelines mushroom laterally and spread down the slope of the interface between saprolite and colluvium. Locally this slope may be opposed to the surface slope.

The quartz stones may be rounded, sub-angular or angular and are often a mixture of these forms, which can be seen to relate to the state of weathering of the feeding stringer in the saprolite. Relatively unaffected quartz bands yield angular fragments. In other cases the stringers are already weathered and rounded in the *in situ* saprolite. Fig. 1 shows an example from Zimbabwe. Here the quartz stringer, exposed in a roadside gully, has been weathered to the extent that it forms a sheet of precareously balanced rounded fragments. Quite clearly, it is very doubtful if the roundness of fragments in a stone-line can be used with confidence to deduce movement by fluviatile activity. This point is clearly made where dykes outcrop within areas of acidic basement rocks in Zimbabwe. The basic rocks weather less readily, so that the weathering profile above them thins and, where outcrops occur, flat oval cobbles are not uncommon. These have clearly been rounded by weathering along joints rather than by fluviatile activity since it would be unrealistic to propose the former existence of a river which ran along the top of the exposed dyke.

Fig. 2 shows a profile exposed by the incision of the Linthipe River, south of Lisiye Hill, Linthipe, in Malawi. Again, rounded quartzitic fragments feed the stoneline. In detail, some of the rounded stones in the stoneline, for example A in Fig. 3, have become 'sugary' and are disintegrating as a result of the more aggressive leaching situation higher in the profile. Directly below the stoneline, the upper boundary of the saprolite has a delicately convoluted form (B) with fragile clasts of saprolite above it (C), features typical of a dissolution front. Where there is no stone-line, the interface between saprolite and colluvium may be very diffuse. A core drilled through an interfluve near Magomero in Malawi, as part of the BGS

Basement Aquifer Project, penetrated some 6 m of clayey sand colluvium before reaching saprolite. The boundary was diffuse and difficult to place, with small clasts of saprolite 'floating' in the colluvium up to 3 m above the saprolite.

## Dambo-peripheral profiles

These profiles occur between presently active dambo (seasonally waterlogged) and the interfluves. The term 'palaeodambo' has been proposed for profiles in these situations as there is clear evidence (MCFARLANE 1986, KAY & MCFARLANE 1986) that the dambos were formerly more extensive and that reduction of their area, accompanied by insetting within the landscape, has resulted in the exposure, to leaching, of what was formerly dambo clay. It is in the base of this palaeodambo clay that the slope-bottom pisolithic laterities are precipitated, the iron deriving from the interfluve profiles.

As with the interfluve profiles, stone-lines occur sporadically, directly above the saprolite. They lie at the base of the lateritised palaeodambo clay. It is a feature of both palaeodambo and dambo clays that in addition to quartz sand 'float' larger fragments of quartz occasionally occur suspended within the clay or lateritised clay. The form of these quartzitic stones is varied. Some are regular, some rounded.

Where there are no quartz stringers, as with the interfluve profiles, the boundary between lateritised palaeodambo clay and underlying saprolite is very diffuse. This is well seen in a core drilled on the flank of Chimimbe dambo, Malawi, by BGS and donated to the International Interdisciplinary Laterite Reference Collection (CORLAT) at the International Soil Reference and Information Centre (ISRIC) in Wageningen, Holland. This core exposed a very vague boundary between lateritised palaeodambo clay and saprolite, with the saprolite irregularly invaded and replaced by the clay, at a depth of about 4 m (Fig. 4a). Interestingly, a 1.5 m monolith, also cut for CORLAT (Fig. 4b), located some 5 m from this core, in a direction parallel to the dambo edge (that is, in the same catenary position but slightly displaced laterally) bottomed on a coarse quartz gravel (predominantly rounded). The basal gravel thus occurs some 2.5 m *higher* in the profile than the base of the clay in the core. This not only points to a highly irregular interface between palaeodambo clay and saprolite but also casts serious doubt on any proposal that such basal gravel below dambo clay is the basal member of a fluviatile succession (FRESHNEY 1987).

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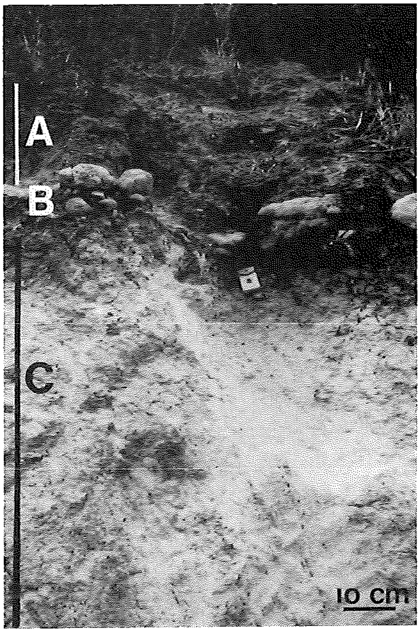

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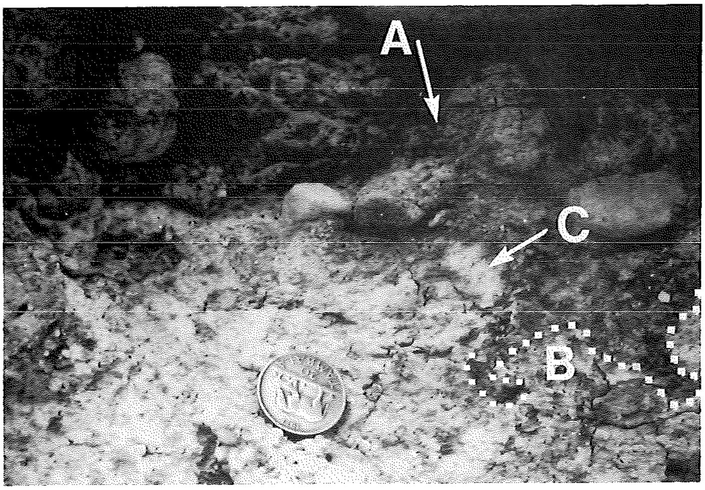

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Fig. 1. – A quartz stringer in saprolite, exposed in a roadside gully. As a result of weathering it forms a sheet of precareously balanced rounded fragments.

Fig. 2. – A profile in the Linthipe district of Malawi. The sandy colluvium (A) overlies saprolite (C), with a quartz stone-line (B) at the interface.

Fig. 3. – Detail of the Linthipe interface. Stones are of mixed form. Example A is rounded and becoming "sugary". The upper boundary of the saprolite has a convoluted form (B) with clasts (eg. C) of saprolite becoming isolated from the main body of the saprolite.

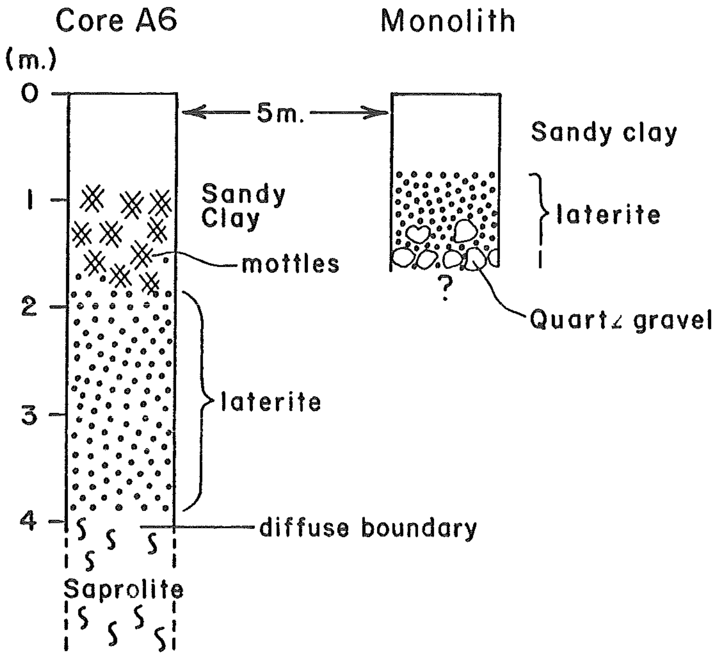



Fig. 4. – Characteristics of the upper parts of a dambo-peripheral profile near Magomera, Malawi.

In short, as with the interfluve profiles, stonelines are local and directly linked with the availability of 'stones' from quartz stringers. Where these do not occur, the boundary is transitional. Again, it is highly irregular.

## Dambo profiles

The origin of dambo 'sediments' is a topic of some debate (e.g. *Zeitschr. Geomorphol.* 1985, N.F., Suppl.-Bd. 52), proposals ranging from fluviatile to weathering residua, with compromises in the form of fluviatile reworking of residua and weathering of fluviatile deposits. Clearly, the nature and configuration of the boundary between dambo clay and underlying saprolite are crucial to this debate. Figure 5 shows a transect across the Chimimbe dambo, Malawi. It is based on data made available by coring and pitting, which was part of an intensive study of dambo sediments by BGS (FRESHNEY 1987). The majority of the coring was by Cobra Piston and Minute Man, lightweight narrow bore corers, which failed to penetrate where stone-lines

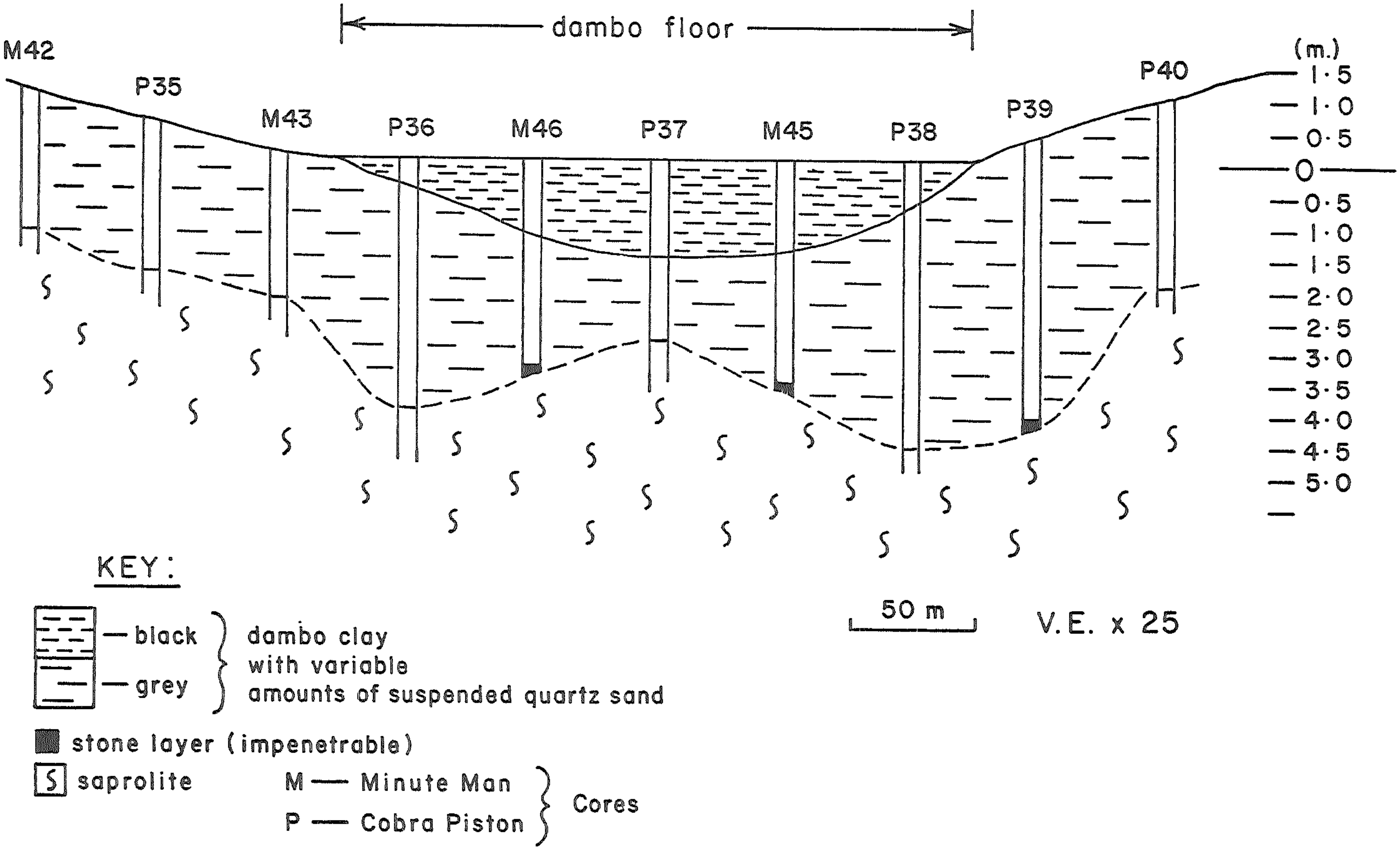



Fig. 5. – Transect across Chimimbe dambo, Malawi.

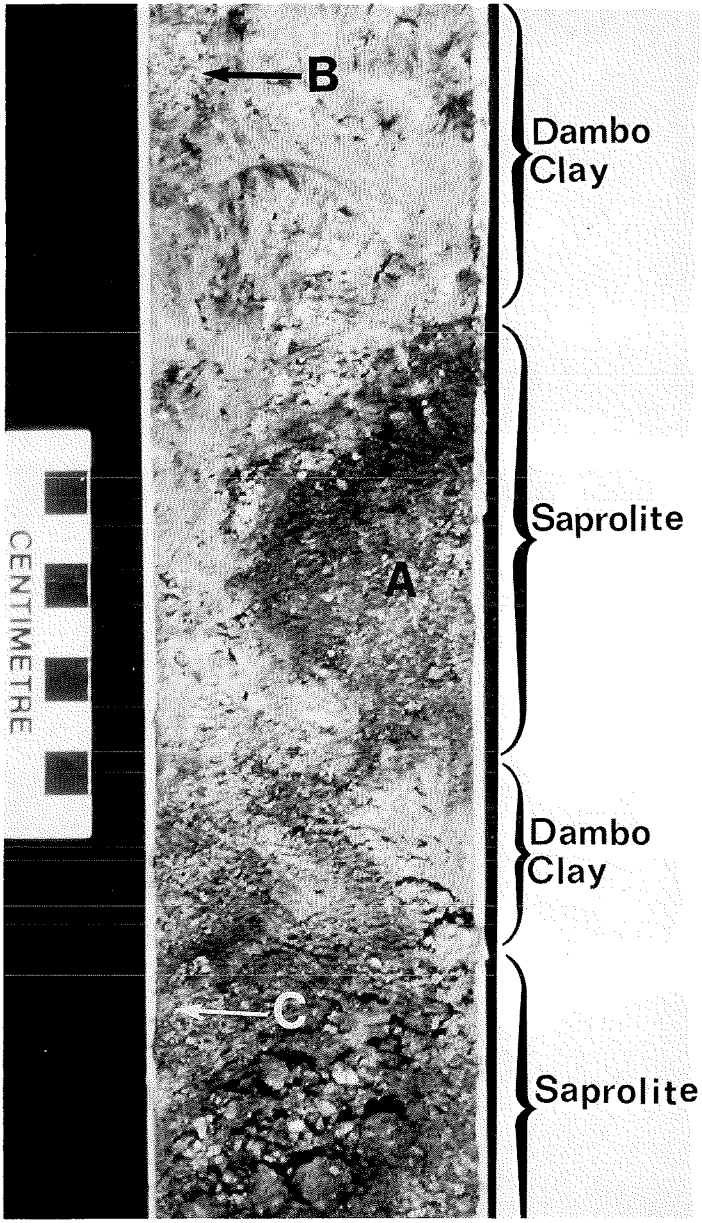
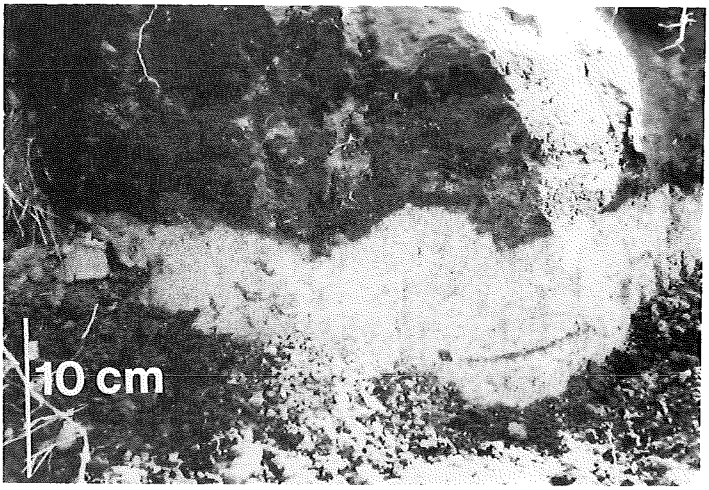



Fig. 6. – Detail of the interface between dambo clay and underlying saprolite in a 4 inch diameter core from Chimimbe dambo. A clast of saprolite (B) occurs suspended within the clay above the interface. A near-clast of saprolite (A) is only linked with the saprolite by a thin 'neck'. An invasion of dambo clay occurs within the main body of the saprolite (C).



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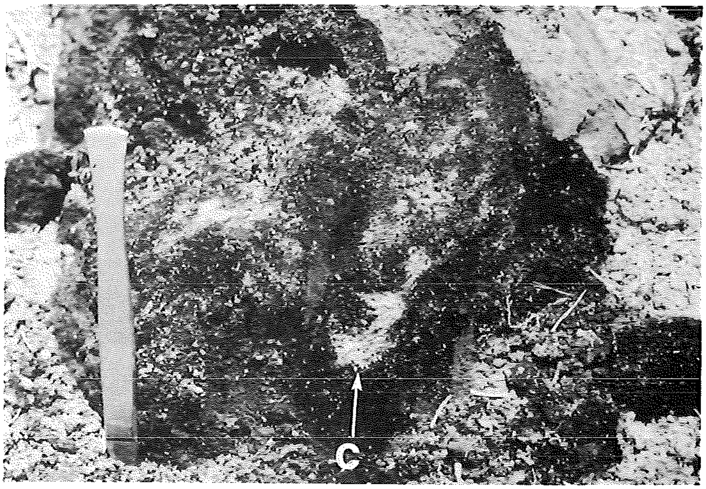

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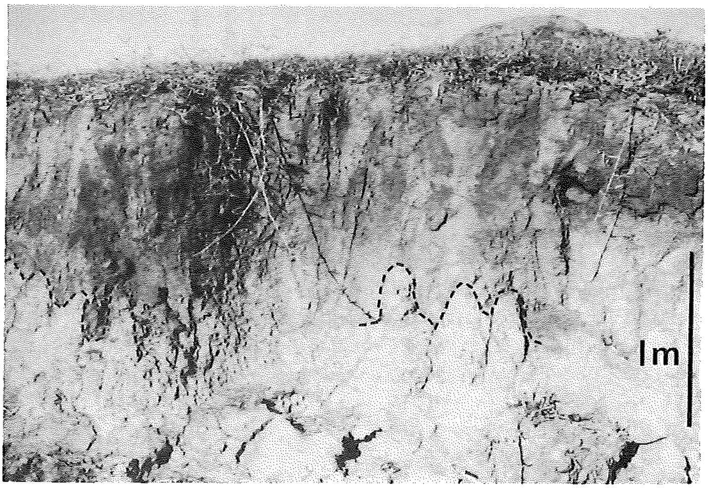

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or basal gravels occurred. In the absence of these, deeper penetration into saprolite was easily achieved. On the basis of this performance, gravels were located as shown in the figure and it is evident that these are not situated where the interface is lowest, such as would be expected if they comprised the basal member of a fluviatile succession. One large diameter core (a 4 inch diameter Triple Tube Corer), located where there was no gravel (Fig. 6) showed that the clay/saprolite interface is highly convoluted. A near-clast of saprolite occurs which is only linked with the saprolite by a thin 'neck' (A). A saprolite clast (B) occurs suspended in the overlying clay, and there are invasions of clay within the main body of the saprolite (C). There seems little doubt that this is a dissolution front, with the dambo clay replacing the saprolite (hence the suspended quartz 'float'). Similar features are readily seen in Zimbabwe where the dambo clay is thinner and where shallow, hand-dug wells often expose the interface. Figure 7 shows an example, in a trench near Mukumba School, Seki district. Figure 8 shows an irregular saprolite clast suspended in the dambo clay above the saprolite boundary, in a dug well near St. Nicolas School, Seki. Many of the gullies which are incising the dambos provide good long-profile exposures of the interface and figure 9 shows the 'karstified' form of the saprolite/clay interface at Murape.

In summary (Fig. 10), stone-lines occur sporadically above the saprolite in the profiles in all three catenary positions, interfluve, dambo-peripheral and dambo. The roundness or angularity of the stones appears to relate to the state of weathering of the quartzitic feeders. Where no such feeders occur the interface between saprolite and surficial material is a highly irregular dissolution front, convoluted or transitional and with saprolite clasts suspended above the front in the surficial materials. The stone-lines are thus linked with a dissolution front in such a way as to indicate a genetic relationship, that it, they are essentially residual.

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Fig. 7. – An example of the irregular, slightly convoluted interface between dambo clay granitic saprolite, commonly seen in shallow pits in Zimbabwe, where the dambo clay is thin.

Fig. 8. – An irregular clast of granitic saprolite (C) suspended in the dambo clay above the saprolite boundary. (Scalpel handle for scale).

Fig. 9. – A long-profile exposure of the interface in a gully near Murape, Zimbabwe. Note the 'karstified' configuration, with the saprolite forming rounded 'highs' protruding into the clay.

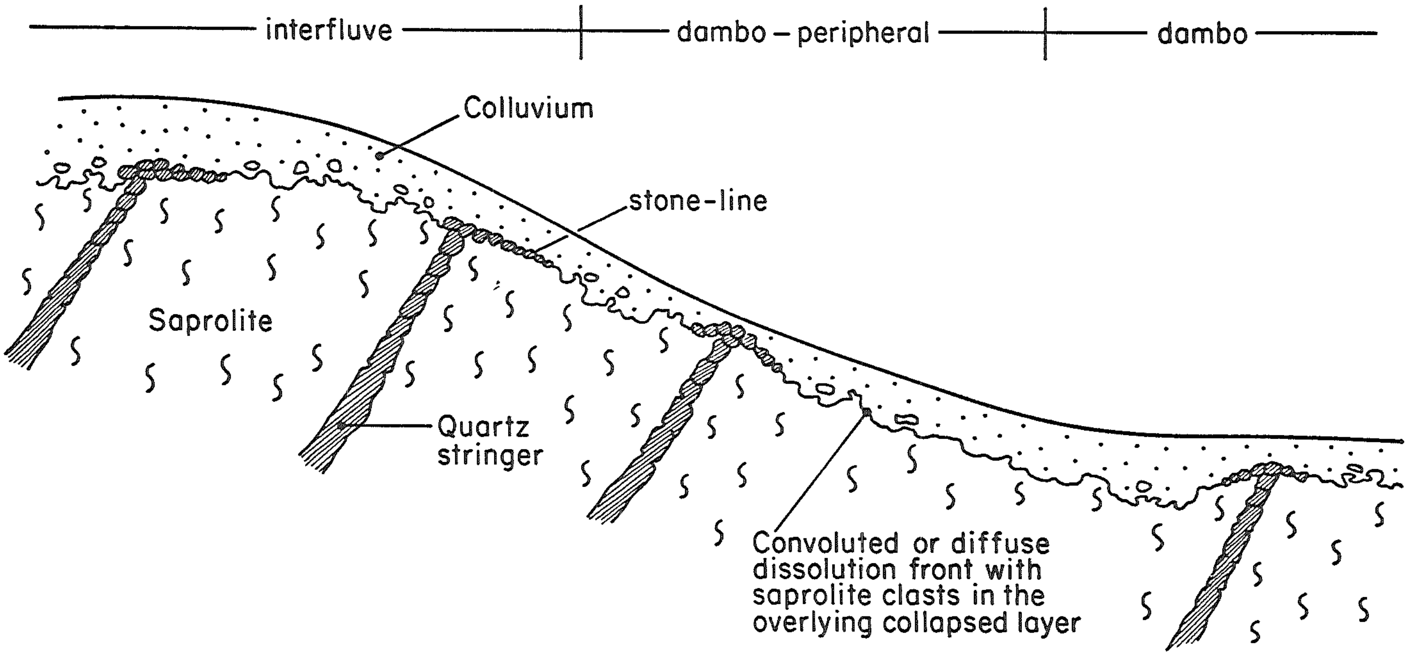
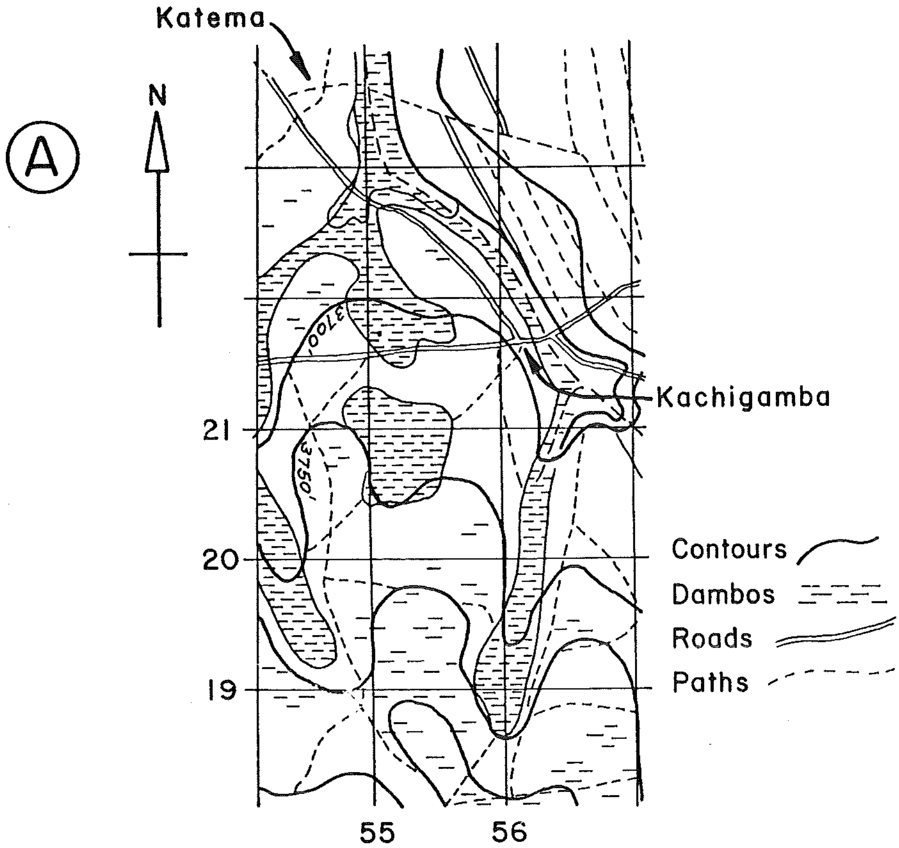



Fig. 10. – Diagrammatic representation of the interface between saprolite and surficial materials in the three catenary positions, interfluve, dambo-peripheral and dambo, in Malawi.



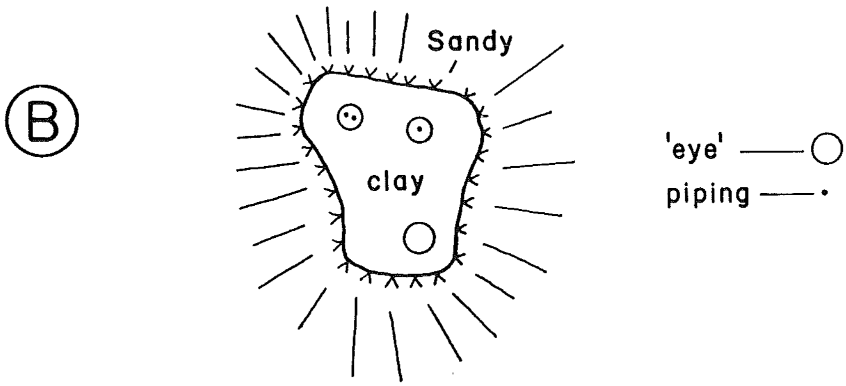




Fig. 11. – An example of a discrete dambo in Malawi (Masidi, 1333 B3). (A) The wider context. (B) Micromorphology. – 1 km grid.

Fig. 12. – An example, from Malawi, of piping in the clay within an 'eye' at the base of an enclosed dambo.

Fig. 13. – An example of a tiny patch of surviving dambo clay at the base of a wide, shallow, sandy depression.

## The configuration of the interface

Exposures which show stone-lines almost invariably provide only a two-dimensional view of the interface. In cuttings parallel to the slope, the rises and dips of the interface might be interpreted as former gully or sheetwash surfaces, pertaining to a system of downslope water movement. However, even in sections at right angles to the surface slope, similar rises and dips occur and this appears to indicate that the interface is basined, the dips being discrete features rather than part of an integrated fluviatile system. This applies to all three catenary positions. For example, a long profile section cut in a dambo by the spillway of a dam near Madisi, in Malawi, showed a stoneline with dips running transverse to the slope of the dambo floor. In many cases the surfaces of dambos are dimpled with small depressions, evidently local subsidence features. Listric surfaces and curvilinear cracking at depth in dambo clay profiles also indicate stresses which may be related to subsidence (McFarlane 1986).

On a larger scale, basining occurs widely in Malawi. Mapping of the distribution and configuration of the dambos, from the 1 : 50,000 topographic maps in the Lilongwe area showed (McFarlane 1986) that although the system is now predominantly integrated, discrete enclosed pockets of dambo also occur. These are inset up to 10 m into the landsurface and evidently represent surviving patches of a formerly more extensive dambo system, basins of which became isolated as the dambo area was reduced. These isolated dambos show features indicative of ongoing insetting, the result of continuing leaching downwards at their base. Fig. 11a shows an example of a discrete dambo, perched on the nose of a spur. In detail (Fig. 11b), there are three discrete 'eyes' inset into the generally flat floor of the dambo, two of which have piping at their base (Fig. 12). These 'eyes' are evidently the loci of preferred passages for downward moving water and hence differential leaching and saprolite collapse. At the margin of this dambo, a hand-dug well exposed a typical stone-line, at the base of the lateritised palaeodambo clay, which slopes downwards towards the dambo centre.

Only the larger of the discrete dambos are shown on the 1 : 50,000 topographic maps. Many more smaller examples can be recognised on the air photos and there are innumerable tiny patches of dambo, too small to be recognised from the photos. Fig. 13 shows one such tiny patch at the base of a wide shallow sandy depression.

**Table 1**

*Mineralogy above and below the dissolution front in the Linthipe profile, Malawi (Plate 2), by XRD (semi-quantitative)*

| | Kaolinite | Quartz | Feldspar | Calcite | Interstratified montmorillonite -mica |
|---|---|---|---|---|---|
| | (%) | (%) | (%) | (%) | (%) |
| Above dissoln. front. | - | 62 | 32 | - | 9 |
| Below dissoln. front. | 44 | 15 | 33 | 9 | 9 |

## Mineral evolution at the interface

Table 1 shows the mineral composition (semi-quantitative) of the Linthipe profile (Fig. 3). The transition from saprolite to colluvium involves removal of kaolinite and relative accumulation of quartz sand and feldspars (orthoclase). Although the mechanical removal of clay can be achieved by pipe flow (MOEYERSONS 1988) it is difficult to see how intact kaolinite can be evacuated ubiquitously through low permeability saprolite. Also against a proposal concerning purely mechanical removal is the absence of equivalent deposits ; complete evacuation in the groundwater is implied and this is unlikely to be achieved unless the clays are broken down. Congruent kaolinite "dissolution" is known to occur but how this is achieved remains problematic in geochemical terms (SCHELLMANN, pers. com. ; MCFARLANE & TWIDALE 1987). A laterite-indigenous micro-organism from Uganda was shown to effect kaolinite dissolution (MCFARLANE & HEYDEMAN 1985) and in order to explore the possibility that indigenous organisms capable of kaolinite dissolution occur in the Linthipe profile, it was sampled for micro-organisms and a leaching experiment conducted using the isolates on a substrate of Linthipe saprolite (POLLARD 1986). Numbers and types of isolates (heterotrophic aerobes) recovered are shown in Fig. 14. Following a 28-day incubation period (aerobic at 25 degrees C), % loss of kaolinite, in comparison with an incubated, uninoculated control, was found by XRD (semiquantitative) to range from 7 to 31%. The control had an initial and final pH of 8.40 and the final pH of the inoculated flasks ranged from 2.6

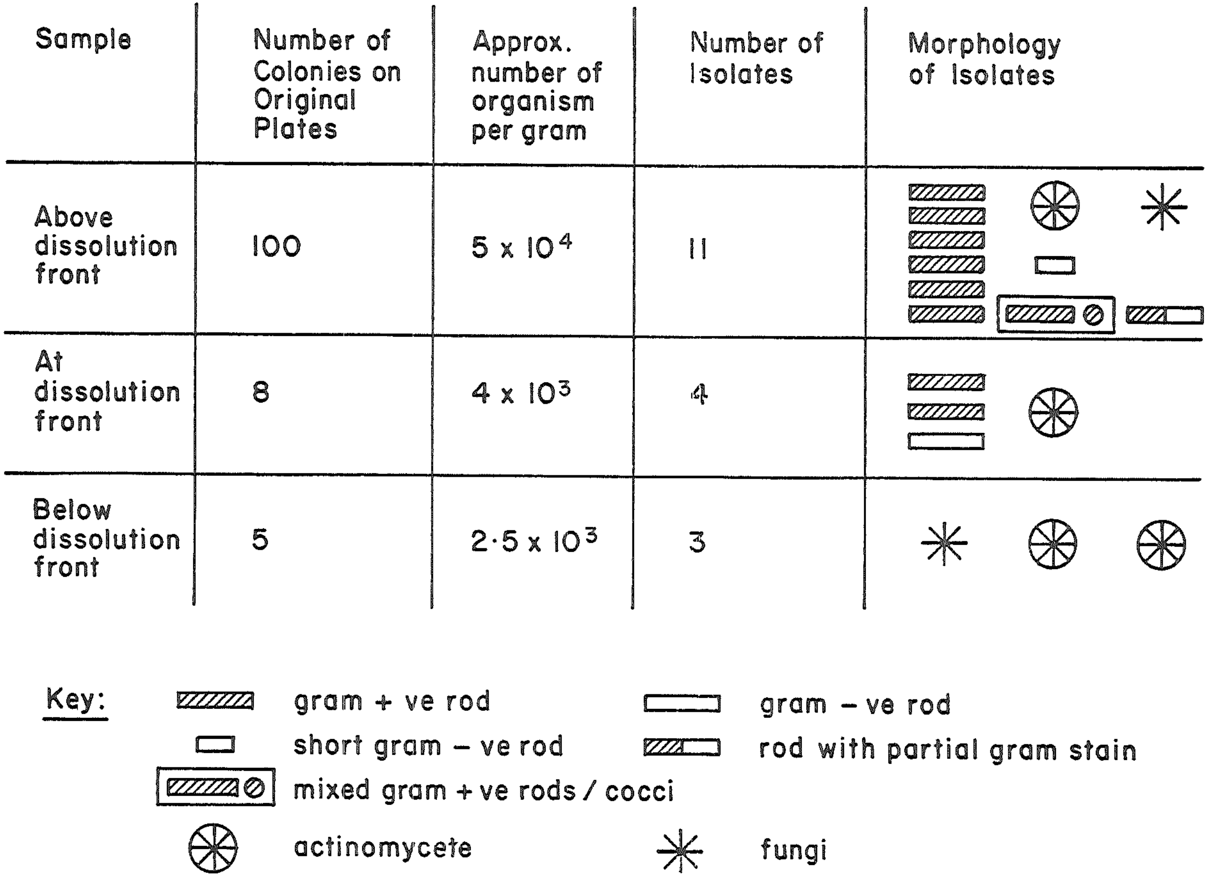



Fig. 14. – Micro-organisms (aerobic heterotrophs) isolated from the Linthipe profile of Fig. 2.

to 4.27. No direct relationship was found between pH and dissolution achieved. This was also found to be the case in other profiles similarly examined (a latrine pit at Mukumba and a well at St. Nicolas School, Zimbabwe and cores from Malawi dambos). For example, one isolate from a depth of 21" (52.5 cms) in the Mukumba School pit achieved some 20% reduction in kaolinite quantity, with a final pH of 7.13 and another at 65" (162.5 cms) achieved 16% reduction at a pH of 8.84. An isolate from a Malawi dambo core achieved a 14% reduction at pH 7.85.

## Conclusions

Stone-lines in the study areas of the African Surface in Malawi and Zimbabwe are, in all catenary contexts (interfluve, dambo-peripheral and dambo), associate with an interface the configuration of which accords with an intracutaneous dissolution front. The stone-lines appear to be residual at this interface, occurring where quartz stringers in the saprolite feed into the collapsed colluvium. The transition from saprolite to sandy colluvium involves removal of kaolinite. Although mechanical removal in the groundwaters is not entirely precluded, dissolution would seem to be required and microbial agents are indicated by leaching experiments using indigenous micro-organisms. These conclusions carry hydrogeological implications which are the subject of ongoing research as part of the Basement Aquifer Project and will be published at a later date.

## ACKNOWLEDGEMENTS

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Mr. T. Heydeman of the Microbiology Department and Dr. A. Parker of the Geology Department, Reading University, supervised the leaching experiments and mineral analyses. We are grateful to Mr. A. Cross for drawing the diagrams and to Mr. J. Watkins for help with the plates. We also wish to thank Dr. E. P. Wright (BGS) and Dr. A. Parker for helpful comments on the manuscript.

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